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THE ELECTRO-PNEUMATIC BRAKE SYSTEM FOR STEAM ROAD SERVICE.[1]

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IN a paper read before the members of this Institute some eighteen months ago, the speaker had something to say regarding air brakes. In this the importance of the air brake in general was given prominence. This evening an attempt will be made to impress upon you the great value of applying electricity as the means of operating the pneumatic or compressed-air brake, the effect of which is obtained by transforming the fluid pressure into a mechanical force, the energy of the vehicle being dissipated by friction between the brake shoes and the wheels of the vehicle.

It has long been known that electricity could add to the flexibility and efficiency of a compressed-air brake, but, so far as steam road equipment is concerned, there are four chief reasons why it has not heretofore been employed for this purpose:

[1] Read by Mr. Walter V. Turner at the meeting of the Mechanical and Engineering Section held Thursday, April 4, 1912.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

First.—Electric current has not been available without special provision being made for it.

Second.—We have not had sufficient knowledge or material at hand to insure a reliable current and connections.

Third.—Because the present air brake has been sufficiently flexible and near enough to being simultaneous for the conditions up to quite recently.

Fourth.—That the pneumatic brake had not been brought to such a degree of perfection as would warrant the application of electricity to it.

(1) Now, however, current is available on practically all the steam trunk lines, as well as on electric railway and steam road electrifications, as nearly all first-class trains are lighted by electricity.

(2) Now the art has developed into a science, in that reliable information and data are at hand with which to make practicable applications, and jumper connections have been brought to such a state of simplicity and reliability that there is no longer need for fear in these respects.

(3) As affecting the action and results of the operation of the pneumatic brake, at least two serious changes in conditions have occurred:

First.—Heavier vehicles.

Second.—Longer trains.

In addition to this, time has become much more important than heretofore because, (1) by congestion of traffic, particularly adjacent to large cities, and (2) because the time lapse as a factor in controlling trains composed of heavy vehicles with the pneumatic brake has become quite serious.

The time element in the brake operation is very important in two ways. In one, it is very necessary, and in the other very undesirable. First, for service operations a time interval is necessary in some steps of the operation; for instance, while it is important that the brake commences to apply on each vehicle of a train simultaneously, it is equally important that the development of the force be obtained gradually, and both these for the same reason, namely, the elimination of damaging shocks and discomforting surges to or in the train. The simultaneous application prevents the slack from first running in and then out, and so on; while the slow rise of cylinder pressure prevents a too

sudden and rapid change of motion,—that is, deceleration, with its consequent disagreeable effect upon the passengers. In emergencies the time element is very undesirable, as to stop is then the only consideration, the requirement being that the consequences be less disastrous than if the accident had not been avoided.

With regard to time, so far as traffic is concerned, every second saved between stations means an increase in the number of passengers it is possible to carry on the same track, as well as a reduction in the schedule time, more trains possible in the same time, and consequently greater realization of the object of running a railroad.

With regard to the time affecting results of pneumatic brake operation, this is manifested with long trains in the increase of time necessary to get the brake applied, and by shocks and stresses, due to the different designs of brake apparatus, or force at the front and rear of the train, at the same instant, and the more rapidly it is attempted to apply the brakes (when rapidity does not include simultaneous action) the greater will be the shocks and stresses. Moreover, when passenger rolling stock has been brought to its present state or condition for the comfort of travellers, any shortcomings, or lack of improvements in this respect, stand out very prominently by contrast, and this is particularly true of what is probably the only remaining two improvements to be made in modern trains, namely, the discomforts produced by the starting and stopping of these trains.

The application of electric current to the brake will not only eliminate the shocks and surges that occur with even the present slow service rate of brake application, but will permit of the application being made more rapidly throughout the train as a whole; thus, as above mentioned, being the equivalent of much more efficient motive power. This will be understood when it is considered that a train in motion is, in effect, a power plant, having a potential the utilization of which can be spread over many minutes, on the one hand, or condensed into a few seconds, on the other. That is, the train may be *permitted* to dissipate its energy in minutes or *compelled* to do it in seconds. Another way to look at this is that a train in motion with the power cut off is the waste product of the power-house (and usually most of it goes to waste, since it is not utilized to save time), and to-day

it is to the heretofore waste product, turned into by-product, that many businesses owe their melon feasts.

With regard to the fourth proposition or assertion, namely, that the pneumatic brake has not until recently reached such a stage as would warrant its being actuated electrically, we may say that electricity would not in any sense add to the braking force, its purpose being to produce simultaneous operation; the application of the brake, in other respects, being identical with the ordinary pneumatic operations. The chief purpose in adding electricity to a pneumatic brake is to instantly transmit the intent of the engineer or operator to each vehicle of the train, thus eliminating the time element and, other things being equal, all shocks and stresses, both in service and emergency, and, in emergency, to shorten the stop somewhat by producing instantaneous application of the brakes on all vehicles in the train.

In the last year or two vehicles have become so large and heavy and trains so long because of large locomotives that the time element between the application and release of the brake from the engine to the last car has become a quite serious factor, since it permits the slack to run in or out, as the case may be, producing discomforting and sometimes dangerous shocks. Operating the service brakes electrically under such conditions then will eliminate this, while, in emergency, it will serve the twofold purpose of preventing shocks and shortening the stops. The retarding force, it must be understood, comes solely from the pneumatic portion of the brake, and until such a brake is installed that will produce the maximum emergency retardation desired or permissible, actuating the brake electrically will not only be a very expensive way to seek improvement, but will be far inferior in results to what could be done pneumatically.

Hereinafter we expect to have more to say on this phase of the matter and to illustrate it by graphic charts; therefore, it may be sufficient to state here that adding electric operation to the old brake, while it will improve matters here wonderfully so far as comfort is concerned, yet it will not compare with what can be done with the strictly pneumatic brake in the matter of stopping force. As the pneumatic brake is now sufficiently developed to warrant the application of electric control and transmission, it reduces to simply a question of expense and wisdom.

Before going into the design of the electro-pneumatic brake, it may be well to show some of its advantageous features and to emphasize the importance of improving the pneumatic brake to its highest degree, before adding electric features, by showing a few curves illustrative of the characteristics of the various improvements or changes in results.

The various curves to follow show comparative performances of service and emergency operation. The advantages of the electro-pneumatic equipment over the strictly pneumatic equipment are clearly shown in Figs. 1, 2, and 3.

The results shown on these curves represent service and emergency stops made from a speed of 40 miles per hour with a 10-car train equipped with the electro-pneumatic brake and an 8-car train equipped with the old-style equipment (P. M.).

Curves 1 and 2 on each figure illustrate the relative decrease in speed as the stop is approached, and curves 3 and 4 show the relative percentage of braking power developed.

The full line curves in each case represent the improved equipment, and the dotted line curves the old equipment.

Fig. 1 represents comparative stops made with a typical service application of the brakes in each case. These curves are plotted on a *time* base to permit of more directly representing the *time saved* and *economy factor* of the electro-pneumatic equipment as compared with the old pneumatic equipment. It will be seen that with the average manipulation, characteristic of the two types of equipment, there is a saving of 20 seconds in the time of stop, in favor of the electro-pneumatic equipment.

It will be evident that this shortening of the time of the stop is due to the fact that a *higher braking power* is obtained in a *shorter time*, and that the service action is started *simultaneously* on each car, as compared with serial action with the old pneumatic equipment.

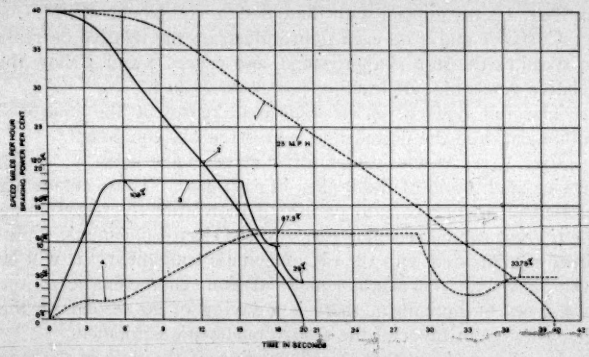
This high percentage of braking power is permissible with the electro-pneumatic equipment by reason of the great flexibility of this equipment; that is, the simultaneous action permits of a high braking force at the start, while the speed is high, and by means of the graduated release feature the braking force can be gradually reduced as the speed of the train decreases.

With the old pneumatic equipment not having the graduated

release feature the serial action in applying the brake, required different manipulations and would not permit of the use of high braking force if smoothness of stop was to be considered.

The maximum braking power with the new equipment (as shown by Curve No. 3), 108 per cent., was obtained in about 4½ seconds, and was retained for about 11 seconds longer, or until the speed of the train had been reduced to about 14 miles per hour, after which the brake was graduated off, the train coming to a stop, with the braking power reduced to 29 per cent. This curve may then be considered as a typical braking power curve showing the graduated release stop.

FIG. 1.



The maximum braking power with the old equipment, (as shown by Curve No. 4), 67½ per cent., was obtained after a lapse of 16 seconds and was retained for about 13 seconds longer, or until the speed of the train was reduced to about 14 miles per hour, at which time the brake valve was moved to release and back to lap, and then a second application was made, the train coming to a stop with the braking power about 33¾ per cent. This curve may then be considered a typical braking power curve showing the usual two-application stop, which is the nearest approach to the graduated release possible with the old equipment.

It will be noted that at the *time* the 10-car (electro-pneumatic) train has come to a stop, the 8-car (old equipment) train

is still moving at a speed of 25 miles per hour (62½ per cent. of its initial speed), with about 39 per cent. of its original energy still remaining to be overcome before it can be brought to a standstill.

This shortening in the time of stop makes possible—higher speeds and shorter schedules, with consequent increased traffic capacity with the same number of cars and power consumption; or the *same* traffic capacity with *fewer cars;* or the same average speeds, schedules, and traffic capacity with *less* power consumption, since the power may be shut off sooner and the train allowed to drift or coast for 11 seconds (645 feet) before applying the brakes to make the stop at the same point.

To further show the difference in the two brake equipments, it is only necessary to mention that if two trains were started on parallel tracks at the same station and both attained the maximum speed, the train equipped with the electro-pneumatic brake would have reached the next station, stopped, discharged passengers, taken on passengers, and be started again before the train equipped with the old brake would have made its stop at the same point.

Even with this possibility of making service stops in a much shorter time, and thus increasing the traffic capacity of the system, there still remains the necessity of keeping the signals spaced the same distance as before, unless the emergency features of the brake are improved as well as the service.

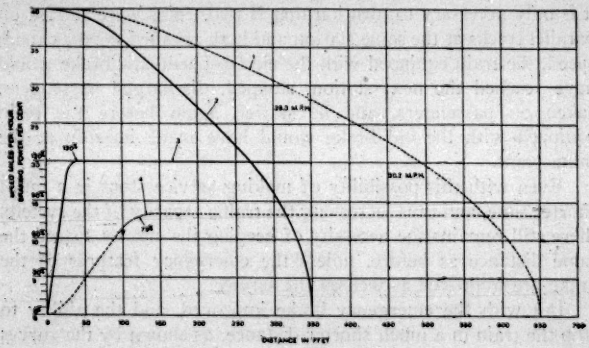
But with the emergency brake improved, and the ability to stop the train in a much shorter distance, as shown by the curves on Fig. 3, it is possible to decrease the distance between signals and still maintain even greater safety than before.

It is possible then to not only run on a much less headway, and in some cases double the number of trains operating over the road, but also longer trains may be operated, since, by the simultaneous and uniform action of the brakes, shocks and stresses are reduced to a minimum, thereby permitting a greater number of passengers to be carried without discomfort, because of the greater number of cars per train and the smooth action of the brake.

Fig. 2 represents comparative stops made with an emergency application of the brakes in each case. These curves are plotted on a *distance* base to compare the *length of stop* and relative

safety factor of the two equipments. It will be seen that the stop with the train having the electro-pneumatic equipment is made in a much shorter distance and less time than that with the old equipment. At the *350 foot mark* where the electro-pneumatic train stopped, the other is moving at a speed of 28.3 miles per hour (71 per cent. of its initial speed), with 50 per cent. of its original energy still remaining to be overcome before the train comes to a standstill. At the *time* the electro-pneumatic train stopped, the old equipment train has run 140 feet farther and is still moving at a speed of 20.2 miles per hour, representing 25.5 per cent. of its original energy.

FIG. 2.



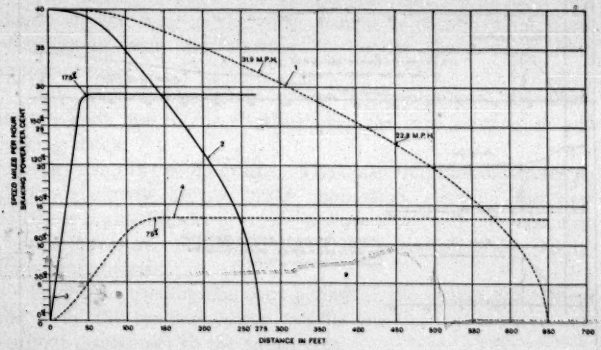
This shortening of the stopping distance with the electro-pneumatic train results from the increased percentage of braking power over that obtained with the old equipment train and also to the fact that *simultaneous* emergency action is obtained throughout the train, as against *serial* action with the old equipment.

It will be noted that the maximum braking power in the old equipment train was only 79 per cent., and was obtained at about *150 feet* from the point where the brakes were applied; while 120 per cent. braking power was obtained in the electro-pneumatic train after it had run about 40 *feet* from the point where the brakes were applied.

Fig. 3 represents comparative stops made with an emergency application of the brakes on an 8-car old equipment train and a 10-car train equipped with the most improved electro-pneumatic brake (main reservoir pressure used in emergency).

The maximum braking power obtained with the improved electro-pneumatic equipment is 175 per cent., as against 79 per cent. with the old equipment. The latter train ran 650 feet before coming to a stop, while the former train was brought to a standstill in *275 feet*. As the old equipment (P. M.) train passed the *point* where the improved electro-pneumatic equipment train stopped, it was running at a speed of 31.9 miles per

FIG. 3.



hour (79¾ per cent. of the initial speed), with 63½ per cent. of its original energy; and at the *time* the improved electro-pneumatic train was brought to a stop, the old equipment train was still running at the rate of 22.8 miles per hour (57 per cent. of its initial speed), with 37½ per cent. of its original energy remaining.

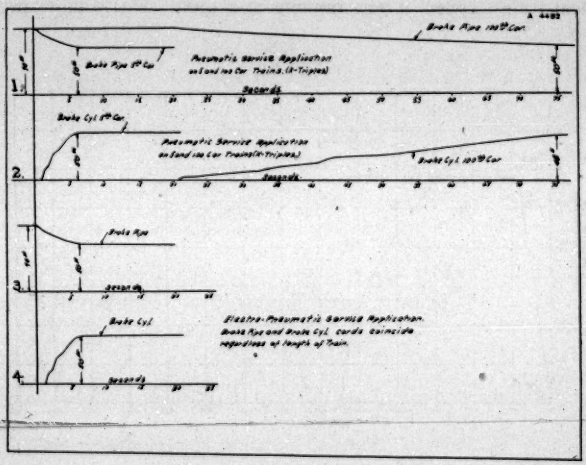
By comparing the curves for the electro-pneumatic equipment and the *improved* electro-pneumatic equipment, it will be seen that the braking power for the latter is greater than the former by 35 per cent. and its stopping distance is 75 feet shorter. This is due to the fact that main reservoir pressure

(approximately 100 pounds) is obtained in emergency operations, thus giving the high braking power.

To further show the immense value and powerful effectiveness of the improved form of electro-pneumatic brake, the following might be added:

The 10-car train, weighing 331 tons and running at a speed of 40 miles per hour, has a kinetic or "wrecking" energy of 17,800 foot tons, equivalent to raising a *ton weight* to the height

FIG. 4.


Brake Pipe 100th Car
Brake Pipe 1st Car
Pneumatic Service Application on Long (100 Car Trains. (4-Triples)
Seconds
Brake Cyl. 1st Car
Pneumatic Service Application on Long (100 Car Trains (4-Triples)
Brake Cyl. 100th Car
Seconds
Brake Pipe
Seconds
Brake Cyl.
Seconds
Electro-Pneumatic Service Application. Brake Pipe and Brake Cyl. curves coincide regardless of length of Train.

of *17,800 feet*, or to raising the *whole train* to a height of *54 feet*.

This energy is entirely dissipated by the brake and the train brought to a stop in 9¼ seconds, and in a distance of 275 feet from the point where the brakes were applied.

Fig. 4 shows four diagrams. Diagram No. 1 illustrates the great difference in the rate of brake pipe reduction between a 5-car and a 100-car train when making a pneumatic service application. Comparing the results obtained from the two trains, it will be seen that with the 5-car train the brake pipe reduction

started immediately, and in 6 seconds time a 20-pound reduction was obtained; while with the 100-car train the reduction did not start until 20 seconds time, and it required 75 seconds to obtain a 20-pound reduction.

Diagram No. 2 shows the rise in brake cylinder pressure resulting from the brake pipe reduction shown in Diagram No. 1, and is proportional thereto.

Diagram No. 3 shows the drop in brake pipe pressure.

Diagram No. 4 shows the rise in brake cylinder pressure resulting from an electro-pneumatic service application. Since the electro-pneumatic operation is simultaneous, the same brake pipe and brake cylinder cards would be obtained on every car in the train, regardless of the length of the train.

The advantages of the electro-pneumatic equipment are clearly shown here, as the time element is entirely eliminated, resulting in each car starting to do its share of braking simultaneously.

This simultaneous action of the brake eliminates the disastrous results due to the slack between the cars running in and causing shocks.

Fig. 5 shows two diagrams. The upper diagram illustrates an electro-pneumatic service brake application, showing the start of rise in brake cylinder pressure in 1.9 seconds and the maximum cylinder pressure obtained in 5.5 seconds, and all brakes applying simultaneously.

Owing to the simultaneous action of the brakes throughout the train, the braking power can be developed in a short time without discomfort to the passengers.

The lower diagram shows the results obtained from a pneumatic service brake application on a 10-car train. The time for starting the rise in brake cylinder pressure is shown as 2.75 seconds, and the time for obtaining the maximum brake cylinder pressure was 11 seconds. The difference in time between the first and tenth cars, in start of rise in brake cylinder pressure, was one second.

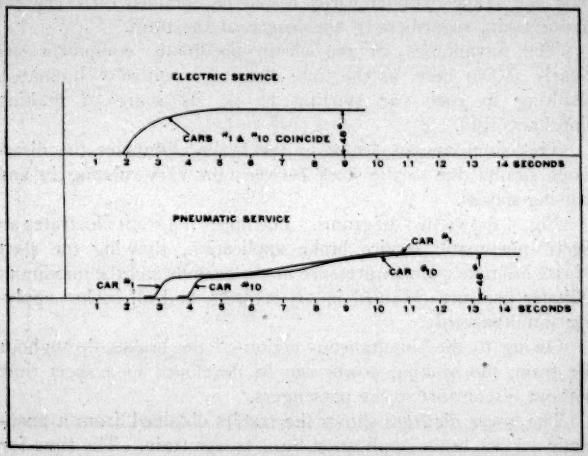
Fig. 6 shows two diagrams. The upper diagram illustrates the results obtained from an electro-pneumatic emergency application on a 10-car train.

The lower diagram shows the results obtained from a pneumatic emergency application on a 10-car train.

Comparing these diagrams, it will be seen that the only difference is in the time of transmission, and is all that should be claimed for the electric feature of the apparatus for emergency operation.

Fig. 7 shows two sets of curves. The upper curves illustrates the results obtained from a pneumatic emergency application with the "P.C." equipment. The maximum brake cylinder pressure was obtained in 2.8 seconds, resulting in a braking power of 180 per cent.

FIG. 5.

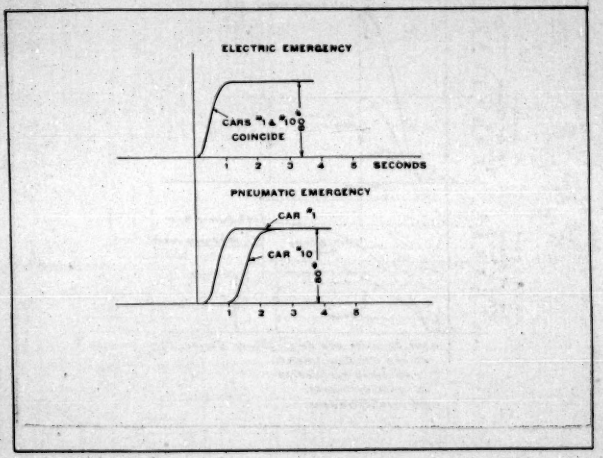

ELECTRIC SERVICE
CARS #1 & #10 COINCIDE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 SECONDS
PNEUMATIC SERVICE
CAR #1
CAR #10
CAR #1
CAR #10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 SECONDS

The lower curves show the results obtained from a pneumatic emergency application with a double "P.M." equipment (a complete brake equipment for each truck). The maximum brake cylinder pressure was obtained in 5.6 seconds, resulting in a braking power of 114 per cent.

These curves graphically illustrate the great difference that exists between different equipments, and that greater gain can be had by improving the pneumatic portion of the brake than by adding the electric features to the old equipment.

Comparing the work done by the two equipments, we will consider the stopping of two 10-car trains running at 60 miles per hour, the energy in these trains being 120.4 foot tons per ton weight. The train equipped with "P.C." equipment will stop in 575 feet shorter distance than the train equipped with the "P.M." equipment. If the train having the "P.M." equipment had the electric features added, without any other improvement, the stop would be shortened only about 70 feet; therefore, the stopping distance would still be 500 feet longer than with the

FIG. 6.



train equipped with the latest improved automatic features ("P.C." equipment). This, because adding the electric features merely eliminates the time of transmission, the greater benefit being prevention of serious shocks and of break-in-twos.

ELECTRO-PNEUMATIC BRAKES.

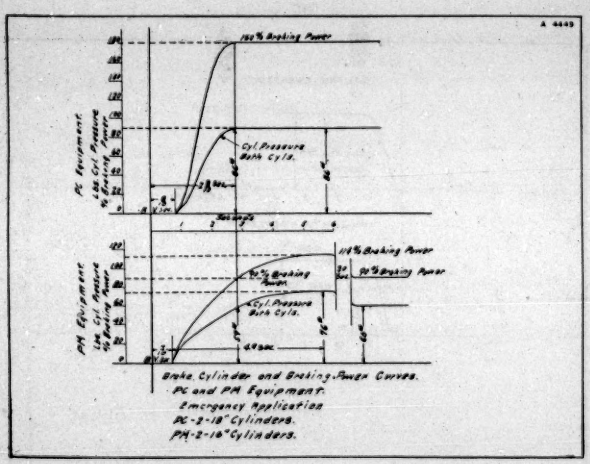
Difference in the conditions to be met, and certain advantages that might be employed with profit, have led to the development and commercializing of four chief types, or forms, of electro-

pneumatic equipments, of which some distinctions can be mentioned.

Traffic conditions, such as exist on the Interborough Rapid Transit Company's subways, very fittingly illustrate the necessity, as well as the advantages, of the electro-pneumatic system of brakes.

At the present time this road is carrying over one million passengers per day, and to handle this large number of people

FIG. 7.



it is necessary to run trains of 10 cars at speeds as high as 40 miles per hour, and on a headway of 90 seconds.

In order to maintain the schedules with these heavy trains and to enable a train to stop, discharge passengers and start again without, in any way, delaying the following train, the highest permissible rates of acceleration and retardation are necessary. To obtain the former, new and improved motive power was installed with which it is possible to obtain a rate of acceleration of 1½ miles per hour per second (about three times that possible with the modern heavy passenger locomotive). To

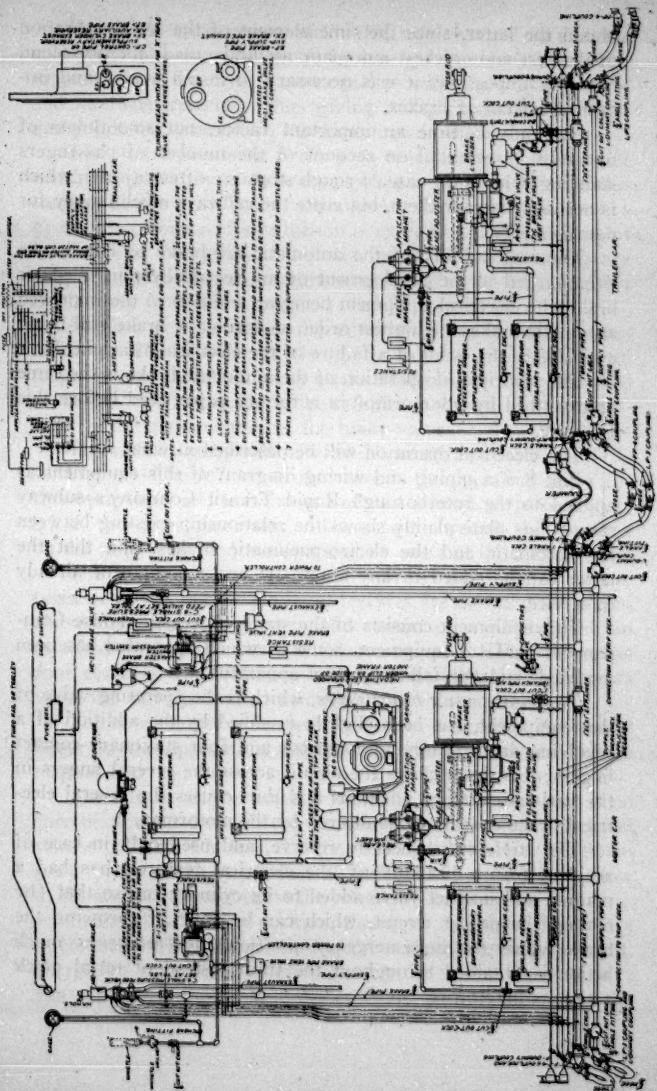


FIG. 8.

obtain the latter, since the time element of the serial operation of the best and quickest automatic air brake made the 90-second headway impossible, it was necessary to install a new and improved system of brakes.

Not only is time an important factor, but smoothness of operation is essential on account of the number of passengers standing, who in the case of rough stops are often injured, which is not only bad for them, but costs the railways much money for damages, etc.

The impossibility of the automatic air brake to handle the situation led to the development of an electrically-controlled air brake, the electrical equipment being an addition to the improved automatic brake, the highest order of pneumatic brake still being available in the event of a failure of the electrical attachments.

The principle of operation of the automatic brake is the same as described by your orator in a former paper read before this Institute.

The electrical operation will be described in what follows:

Fig. 8 is a piping and wiring diagram of this equipment as applied to the Interborough Rapid Transit Company's subway cars. This plate plainly shows the relationship existing between the automatic and the electro-pneumatic brakes, and that the latter can be added to any automatic brake equipment already in service.

This equipment consists of the standard Westinghouse Company's "AMR" equipment, some of which apparatus has been modified, and the following new apparatus:

The motorman's brake valve, which is the operating valve of this equipment, has been slightly modified by the addition of a revolving drum (carrying contacts) and four stationary contact fingers; this drum closes the circuit across the several fingers in the various electrical positions and thus causes the several electrical brake operations as desired by the motorman.

The *triple valve,* held in reserve, and used only in case of accident to, or disability of, the electrical features, has had a magnet and magnet valve added to its cylinder cap so that (by closing the proper circuit, which can be done by throwing the brake valve to the emergency position) *instantaneous* quick action is obtained throughout the train instead of serial quick action as heretofore.

The check valve case of this valve was changed so that the rubber-seated valve (formerly the emergency valve) allows the supplementary reservoir air to equalize with the brake cylinder and auxiliary reservoir, thus giving a higher maximum emergency cylinder pressure in less time than formerly.

The electro-pneumatic brake pipe vent valve is a new device which automatically vents brake pipe air to the atmosphere (thus causing serial quick action throughout the train) whenever a given rate of brake pipe reduction is exceeded. The operation of this valve in emergency also closes the circuit to the emergency magnet line, so that an instantaneous quick action or emergency is obtained whenever current is "on."

Another new device is the *application and release magnet bracket.* This device, as the name implies, consists of two magnets and magnet valves by means of which air can be admitted to, or exhausted from, the brake cylinder at the will of the motorman by the manipulation of the brake valve.

The various parts will now be described in detail.

Fig. 9.—The *ME-21 brake* valve is the operating valve for this equipment, and is composed of two distinct parts—one electrical, the other pneumatic. These two portions are mounted on the same shaft and are operated by one and the same handle.

The pneumatic portion of this valve is the same as former types of valves, but the electrical features are new and are placed above the pneumatic portion, and consist of a revolving drum attached to the same shaft as the rotary valve. This drum has four contacts which connect with corresponding contact fingers when the valve is rotated through its various positions.

The upper finger is connected direct to the trolley, the second finger to the application magnet line, the third to the release magnet line, and the lower one to the emergency magnet line.

The release magnet valve is normally open, hence there is no current flowing through the brake valve when in the electrical release position, which is also the running position for the pneumatic brake, and any air that is in the brake cylinder can flow to the atmosphere and cause the release of the brake.

In the electrical lap position, the upper and third fingers are in contact with the drum, closing the release magnet line circuit, energizing the release magnet, closing the release magnet valve and separating the brake cylinder from the atmosphere; in the

electrical service position, the first, second, and third fingers are in contact with the drum, and current is still flowing through the release magnet; the application magnet line circuit is also closed, thus opening the application valve, which, in turn, opens the relay valve and allows auxiliary reservoir air to charge the brake cylinder.

In all electrical positions of the brake valve the brake pipe charging port is open, thus maintaining the brake pipe and auxiliary reservoir air at initial pressure. In the pneumatic lap position all ports are blanked. In the first pneumatic service position there is a small port open from the brake pipe to the atmosphere, which gives a suitable rate of brake pipe reduction to cause a service application on a 5-car train.

In the pneumatic lap position and first service position the electrical connections remain the same as in electrical application position; these connections are maintained in these positions to insure getting a brake application in case the motorman should move his brake valve beyond the electric application position.

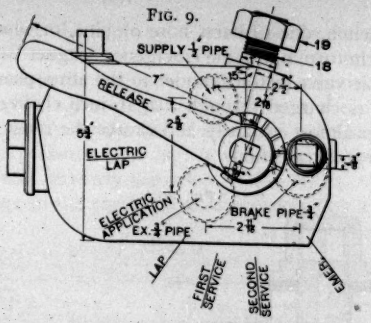
In the second pneumatic service position there are two ports open from the brake pipe to the atmosphere which give a suitable rate of brake pipe reduction to cause a service application on a 10-car train.

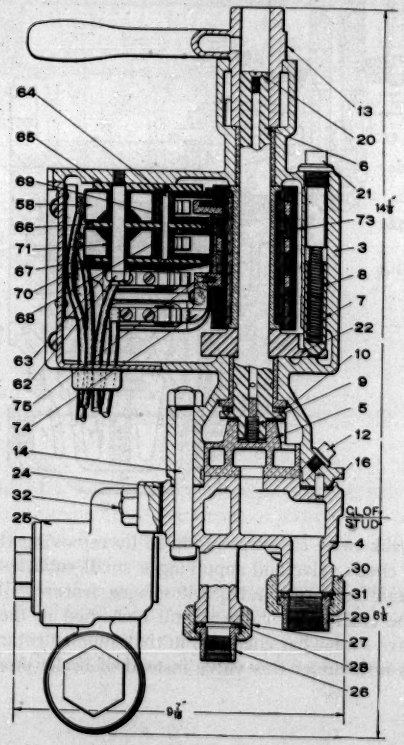
In the emergency position there is a large port opening from the brake pipe to the atmosphere which gives a rapid enough rate of brake pipe reduction to cause the brake pipe vent valves to operate in quick action. At the same time connection is made between the trolley and emergency line contacts so that, if the current is "on," the emergency line and magnet are energized and cause the emergency magnet valve to open, and this, in turn, forces the triple valve over to the emergency position; thus, with current "on," the electro-pneumatic emergency will prevail, otherwise purely pneumatic emergency will result.

Fig. 10 shows a diagrammatic cut of the *R-2-C triple valve*, which is used with this equipment. This is the standard R-2 triple valve slightly modified by embodying a new cylinder cap having a magnet and magnet valve, and a new check case.

The magnet on the cylinder cap is connected to the emergency magnet line and is energized whenever this circuit is closed (which closing may be caused by the brake valve being moved to the emergency position, or by the brake pipe vent valve

FIG. 9.


SUPPLY 1/2 PIPE
19
18
RELEASE
ELECTRIC LAP
ELECTRIC APPLICATION
EX. 1/2 PIPE
BRAKE PIPE 1"
LAP
FIRST SERVICE
SECOND SERVICE
CAUTION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73
3
8
7
22
10
9
5
12
16
CLOF STUD
4
30
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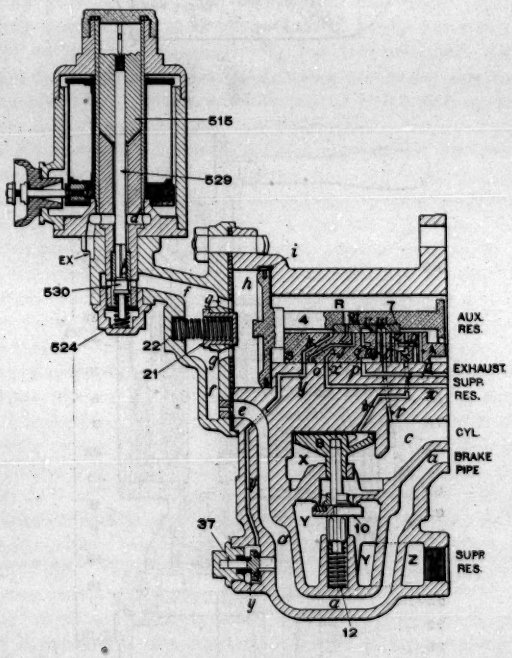
27
28
26

closing its switch, due to burst hose or pipe, or separated train, etc.). This, in turn, opens the emergency magnet valve and connects the triple valve piston cylinder to the atmosphere, and since this cylinder is charged through a 1/16-inch choke, its pressure drops to zero almost instantly and causes the triple valve to go into the emergency position.

FIG. 10.

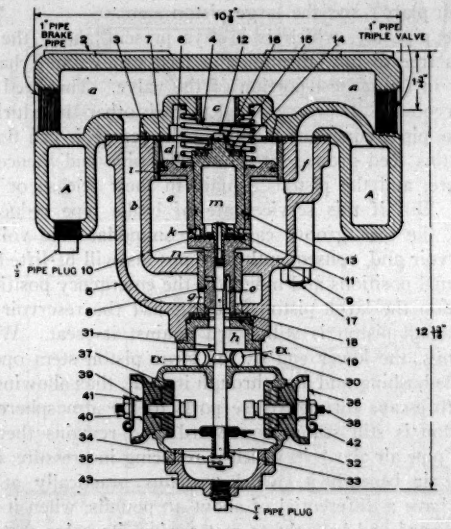


The check valve case was modified by removing the ordinary brake pipe check valve and supplying a small rubber-seated valve for the quick recharge and quick service features of the triple valve. The emergency valve is still embodied in the valve, but its duties are somewhat changed, in that supplementary reservoir pressure is now under this valve instead of brake pipe as hereto-

fore. Thus, when the triple valve moves to the emergency position, air from the auxiliary reservoir forces the emergency piston downward, unseats the emergency valve, and permits the supplementary reservoir air to equalize with the brake cylinder and auxiliary reservoir. By the use of this large valve the maximum brake cylinder pressure is of higher value and is obtained more quickly than was formerly the case.

This change in the check valve case makes this a plain auto-

FIG. 11.

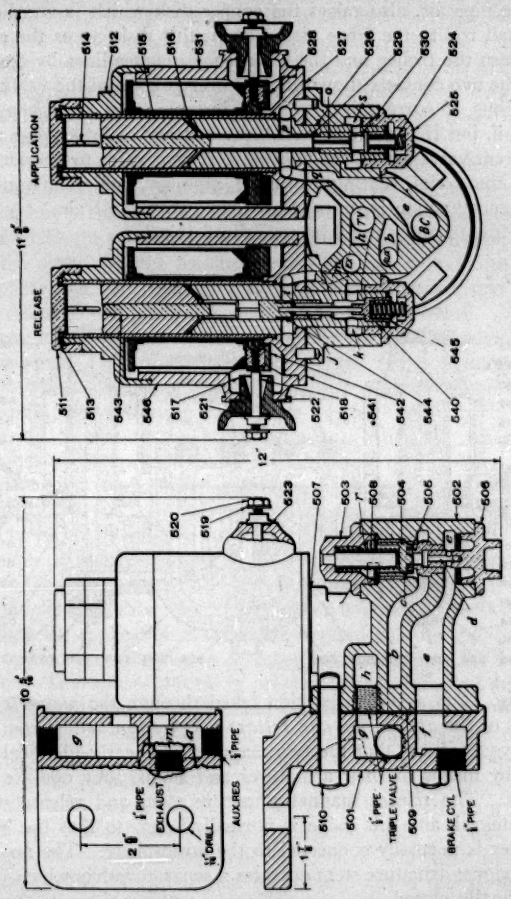


matic instead of a quick action automatic, triple valve as previously, and, consequently, since trains of more than five cars are to be handled, it will be necessary to have a brake pipe venting device in the equipment.

Fig. 11 shows the *electro-pneumatic brake pipe vent valve,* standard for this installation. This valve is placed in the branch pipe leading from the brake pipe to the triple valve, and is composed of a small reservoir and a body which encases a double or

telescoping piston device. Brake pipe air enters the cored passage leading directly through the reservoir portion and flows through same to the brake pipe connection of the triple valve; this cored passage has a side outlet which leads down to the top of double piston, forcing both down against their seats, so that brake pipe air cannot escape around the lower end of the large piston's stem, and air from the chamber under the large piston cannot escape past the lower end of the small piston to the atmosphere. The chamber inside of the small piston is always open to the atmosphere by means of the small vent through the screw (which holds its seat in place) and the large piston stem.

Brake pipe air, which is always present above the double piston, is free to flow through the feed groove and charge the reservoir in the largest portion of the valve. This feed groove and reservoir are so proportioned to each other that during service brake pipe reductions the air in the reservoir can flow back through this feed groove into the brake pipe and thence to the atmosphere, and the pistons remain in their release or normal position. But if this service rate of brake pipe reduction be exceeded, the feed groove cannot accommodate the volume of this reservoir and, consequently, the pistons will be lifted out of their normal positions and moved to the emergency position. In this position the large piston rests against the reservoir gasket and the small piston is still down against its seat. With the pistons thus, the lower end of the large piston stem opens the ports in its bushing and also through its seat, thus allowing brake pipe air to escape through these ports to the atmosphere. The small piston is still seated downward, and remains there until the brake pipe air above it, which is reducing in pressure, and the reservoir air beneath it, which remains practically at initial pressure, have a differential of about 40 pounds, when it will be moved upward and brought to rest against its valve seat. This 40-pound differential is necessary, owing to the small area exposed to reservoir pressure, as against full area of the piston to the brake pipe pressure. When this piston lifts and seats upward, the row of ports around its lower end are opened, and the reservoir air can then drain to the atmosphere. When this reservoir pressure has dropped to a point slightly lower than that in the brake pipe, the large piston will be returned to its normal or release position, the smaller piston remaining seated upward until the brake pipe pressure is again restored.


APPLICATION
RELEASE
11"
12"
10½"
2⅜"
1½"
514
512
515
516
531
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527
526
529
530
524
525
511
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546
517
521
522
518
541
542
544
540
545
523
520
519
507
503
508
504
505
502
506
1" PIPE
EXHAUST
¼" DRILL
AUX. RES
1" PIPE
510
501
1" PIPE
TRIPLE VALVE
509
BRAKE CYL
1" PIPE

FIG. 12.

The raising of the pistons, due to the sudden reduction of brake pipe air, also raises the copper disk which is attached by a small rod to the large piston stem; this disk closes the circuit between the trolley and the emergency magnet lines by connecting the two contacts shown in the lower portion of the valve.

Thus, if current is "on," the instantaneous emergency will prevail, but if current is "off," the venting of brake pipe air at any vent valve causes the next nearest vent valve to operate, and thus the serial venting of brake pipe air, and, consequently, emergency action is propagated throughout the train.

Figs. 12 and 13 will be considered jointly.

FIG. 13.

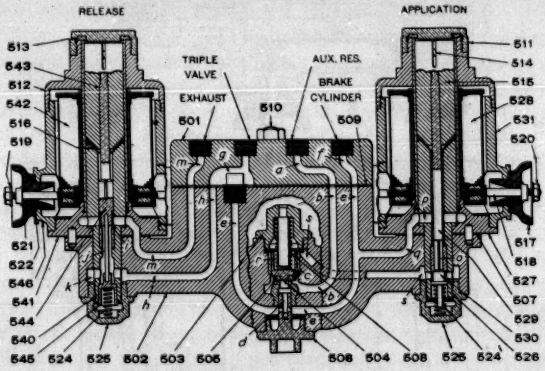


Fig. 12 is a vertical section taken through the *magnets* and valves of the *application and release magnet bracket*. From this view you will see that the two magnets are nearly identical and that, by means of their armatures and stems, they operate two valves. The release magnet armature stem and release valve are integral, and this valve is normally open, so that the brake cylinder is normally connected to the atmosphere. The application magnet armature stem operates a separate valve, which valve is normally closed.

Fig. 13 is another view of this bracket, showing a section through the relay valve and the special choke fitting or cap nut.

The magnet bracket has three pipe connections, viz., the supply from the auxiliary reservoir, the brake cylinder pipe, which connects the relay valve to the brake cylinder, and the release pipe, which connects the triple valve exhaust outlet to the magnet bracket. The exhaust opening is also tapped and may or may not be piped to carry the exhaust of the brake cylinder air away from the magnet bracket.

When an electro-pneumatic brake application is desired, the motorman moves his brake valve handle to the electric service position, but in doing so he must pass over the electric lap position, in which the release magnet is energized and its valve closed. Thus the cored passage leading from the brake cylinder to the atmosphere, *via* the triple valve exhaust port, is closed, and any air admitted to the brake cylinder will be retained there. With the brake valve in electric service position the release magnet is held energized, and the application magnet is also energized. This pulls the application magnet armature downward, and its stem forces the application valve from its seat and vents the top of the relay valve to the brake cylinder. Auxiliary reservoir pressure is always present under the outer area of this valve, and by means of a small drilled hole this air can equalize into the chamber above the relay valve, and thus, since the inner area of the under side of this valve is connected to the brake cylinder and thence *via* the release magnet to the atmosphere, the same is held seated. The relay valve chamber is connected to the under side of the application valve, and this chamber is normally bottled up.

When the application magnet is energized and the application valve opened the relay valve chamber is connected to the brake cylinder. This causes a drop in pressure which the small drilled equalizing port cannot supply, and consequently the relay valve is lifted by the auxiliary reservoir air, and the latter is allowed to flow down past this valve and through the special choke cap nut into the brake cylinder.

If the application magnet is energized for an instant and then de-energized, allowing the application valve to close, the pressures above and below the relay valve will very quickly equalize, closing this valve and permitting only a partial application of the brake. This operation may be repeated several times until the maximum brake cylinder pressure is obtained.

If the maximum pressure is desired quickly, the application

magnet is held energized by allowing the brake valve to remain in electric service position. Under these conditions, the relay valve will remain open until the auxiliary reservoir and brake cylinder pressures have equalized, or, if desired, as is here the case, the relay valve may be loaded with a spring, thus making it an excess pressure valve, in which case the brake cylinder pressure will be less than the equalization of the auxiliary reservoir and brake cylinder pressures by an amount equal to the tension of the relay valve spring.

For example, if the tension of this spring represents 10 pounds per square inch on the valve area of the relay valve, then the highest electro-pneumatic service cylinder pressure will fall 10 pounds below the equalizing point of the auxiliary reservoir and brake cylinder pressures, and since the triple valve remains in release position and the brake pipe keeps the auxiliary reservoir pressure at 70 pounds, this brake cylinder will be 70—10, or 60 pounds.

Since the triple valve remains in release position during an electro-pneumatic application, the air admitted to the brake cylinder by the relay valve is free to flow back through the triple valve exhaust port and the magnet bracket release pipe to the under side of the release magnet valve. Then, when the electro-pneumatic release of the brakes is desired, the brake valve is returned to the electric release position, in which the release magnet circuit is broken and the release magnet de-energized. The brake cylinder air then lifts the release magnet valve and flows past the same to the atmosphere.

This release may be made straight away or may be graduated at the will of the motorman.

To graduate the electro-pneumatic release, the motorman moves his brake valve handle to the electric release position for an instant and then back to the electric lap position. By this manipulation the release magnet is de-energized and then is again energized. This permits the release magnet valve to stay open for a few seconds only, and, consequently, a partial or graduated release of the cylinder pressure takes place.

The admission of air to the brake cylinder is direct, so that the rate of rise of brake cylinder pressure may be made whatever is desired, and may also be controlled by the special choke cap nut in the magnet bracket, the area of which choke is made proportional to the brake cylinder volume with which the magnet bracket

is to be used, so that the rate of increase of brake cylinder pressure will be uniform for all sizes of brake cylinders.

The release of the brake cylinder pressure is made through the triple valve exhaust, so that the time of release will be the same for either automatic or electro-pneumatic operation; this also eliminates the necessity of a double check valve or similar device which would otherwise be required to separate the two methods of operation.

The relay valve is used so that we may have an amply large opening between the auxiliary reservoir and the brake cylinder to give the cylinder pressure desired in the required time and still enable this opening to be controlled by a comparatively small magnet.

Fig. 14. The *master brake switch,* with its "no-voltage magnet," further safeguards the brake operation and the train movements.

This device consists of a rotating drum having eight contacts and eight corresponding stationary contact fingers, these contacts and fingers being used in the various positions of the switch. The drum aforementioned is mounted on a shaft which has provision for a suitable handle, so that this drum may be moved to any of its four positions.

The arrangements of the stationary and drum contacts are shown on Fig. 14 (upper right-hand corner).

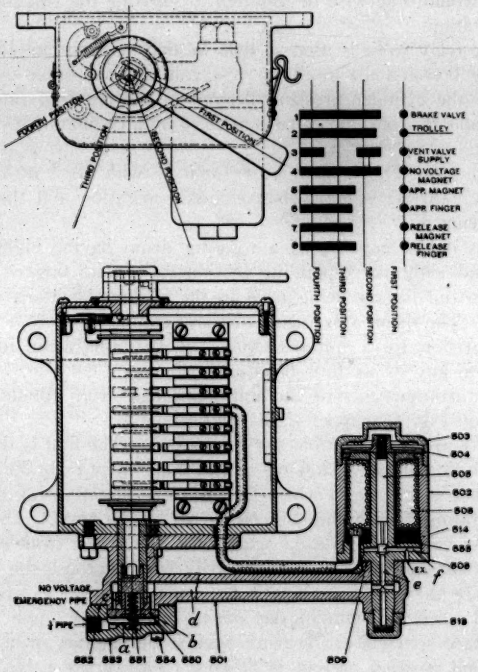
There are four positions for this switch. The first is the one in which no current is flowing to the brake valve or brake apparatus, and is the one in which the switch is placed on all except the operating end of the controlling car in the train. Thus all the brake valves are "dead," except the one at the front end of the first car, and this must necessarily be so because the brake valves are carried in pneumatic lap position on all except this car, and when in pneumatic lap position the trolley, application, and release contacts are bearing against the contact drum. In the second position current is flowing to the brake valve, vent valve, and no-voltage magnet, but the application and release magnet lines are cut out. In the third position all connections are made except to the vent valve; and in the fourth position all electrical connections are closed, so that the entire electro-pneumatic system is available. This is the position for the switch on the controlling end of the train.

The handle of this switch is guarded so that it cannot be re-

moved (as is the case when the motorman leaves his train), except in the first position, in which all electrical connections are broken.

On the lower end of the drum shaft is a small rotary valve

FIG. 14.



which controls air communication between the "emergency valve" and the no-voltage magnet. This communication is closed in first position, but is open in the other positions.

The "no-voltage magnet" is what the name implies; to its armature is attached a valve and stem, which normally closes the

opening from the emergency valve through the emergency pipe and the small rotary valve of the master brake switch to the atmosphere. Whenever the voltage drops low enough to render the electro-pneumatic brakes ineffective, this magnet cannot hold its valve closed against the pressure under it, and thus allows the air from the emergency valve to be vented to the atmosphere and cause an automatic emergency application of the brakes. The switch can now be reset by moving its handle to the first position, and the brakes may then be released pneumatically.

This feature absolutely safeguards against serious accidents or delays which might result from a loss of voltage, and is of particular value where a train is drifting. Otherwise, under these conditions (drifting), the current might fail, and the motorman would be unaware of this failure until he tried to make a brake application, and even then his train would run some distance before he realized that the brakes were inoperative, and by this time even a pneumatic emergency might be unable to prevent collision.

The latest "*synchronizing of pump labor*" scheme, with which, after the system has once been fully charged, one master governor (whichever has the highest "cutting-in" point) will control all the compressors in the train as a unit, consequently the danger of any one compressor running continuously is eliminated.

The foregoing is a description of the electro-pneumatic system as applied to the subway division of the Interborough Rapid Transit Railway of New York City in 1910.

The operation of, and the returns from, the systems have more than met expectations. Also, the equipment has gone a long way to establish the electro-pneumatic brake on a permanent basis, since it has proven itself the safest, most profitable and economical type of brake equipment.

(*To be continued.*)

Resistance and Thermo-electricity of Tantalum. H. PÉCHEUX. (*Mon. Sci.*, ii, 842, 137.)—The resistance increases with the purity of the tantalum filament. The principal coefficient of temperature increases with the purity of the metal. The thermo-electric power increases with the purity of the tantalum. Annealing increases the thermo-electric power.

Petrol Air Gas as an Adjunct to Coal Gas. W. KEY. (*J. Gas Lighting*, cxviii, 425.)—In order to prevent the deterioration in the illuminating power of coal gas due to low temperatures (40° F. and below) at the condenser outlet, it has been proposed to use reversible condensers, the gas at 140° F. being passed alternately through the condensers from the opposite ends. It is proposed, as a cheaper alternative, to prevent excessive deposition of tar in the condensers by introducing from 10 to 20 per cent. of cold petrol air gas through the covers of each hydraulic main. Besides cleaning the condensers and pipes from tarry deposit, the addition of the air gas effects considerable saving in the quantity of lime required and in the expenditure on labor on the purifiers.

Injurious Properties of Magnesium Chloride in Finishing Cotton Goods. E. RISTENPART. (*Z. Angew. Chem.*, xxv, 289.)—An investigation into the tendering of cotton goods when finished with sizes containing magnesium chloride, owing to the liberation of free hydrochloric acid. The following conclusions are reached: (1) An aqueous solution of magnesium chloride does not decompose at temperatures below 106° C., even when heated in a current of air or steam or in the presence of cellulose and any ordinary ingredient of a size. (2) Even when magnesium chloride is heated to 246° C., the free hydrochloric acid formed is only equal to about 2 per cent. of the weight of the salt taken. (3) Tendering of cotton goods finished with a size containing magnesium chloride cannot take place at temperatures below 106° C. Such goods can be exposed to the action of saturated steam and be decatized with it. (4) At higher temperatures, especially if long continued, the goods are tendered. One hundred degrees Centigrade is the highest temperature at which such goods can be safely dried. (5) Within this limit, magnesium chloride can be used with perfect safety, but such goods must not be subsequently subjected to severe hot pressing or calendering, nor exposed to superheated steam.

Preservation of Wood. E. PINOY. (*Comptes Rendus*, cliv, 610.)—Wood may be preserved from the attacks of fungi, such as "dry-rot," by soaking in a solution containing 2 per cent. of potassium bichromate and 1 per cent. of sodium fluoride, and then drying and exposing to light. After this it may be coated with a solution containing 5 per cent. of gelatin, 2 per cent. of bichromate, and 0.5 per cent. of sodium fluoride, which forms a varnish, when dried and exposed to light, and imparts a mahogany brown color to the wood. If already attacked by fungi, the wood must be disinfected, before treatment, with a mixture of denatured absolute alcohol and xylol containing 1 per cent. of corrosive sublimate; it is then steeped in baths of bichromated gelatin, of increasing strength, dried and exposed to light.

THE USE OF GAS FOR HEAT AND POWER; THE TESTING OF GAS.[1]

BY

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THE use of gas for heat and power has rapidly increased in recent years. This is partly due to a reduction in the price of gas and to improvement in the service rendered by gas companies, and partly to the improvement of gas appliances in the direction of greater convenience and efficiency and to the invention of new appliances for the accomplishment of many results in new ways. With more than 1,300 gas companies in the country, with a combined capital of $1,000,000,000 and annual sales of $200,000,000, it is one of the most important of the industries.

I. THE USE OF GAS FOR HEAT AND POWER.

Coal Gas.

The first recorded suggestion of the use of gas for fuel was in the patent taken out in England in 1805 by F. A. Winsor for a process of "extracting inflammable air" from coal. The product was to be applied to heating as well as to lighting; but in spite of his great enthusiasm, Winsor was not successful in bringing about the utilization of gas for fuel, and little was done along this line until about 1825, when the first gas cooker was invented. From that time until about 1880 development was very slow.

One important invention, however, was that of Delbruck, who placed one tube inside another, using one for the gas and the other for the passage of the air, mixing the two at the point of ignition.

What are usually called bunsen burners in connection with

[1] Address delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant, under the auspices of The American Philosophical Society, The Franklin Institute, The American Chemical Society, and The American Gas Institute, in the hall of The Franklin Institute, Philadelphia, Friday, April 19, 1912.

gas stoves are a modification of bunsen burners, invented by Thomas Fletcher of England. The true bunsen consists simply of the familiar open tube of the laboratory with the gas nozzle and air ports at the base. Fletcher was the first to use a cap to diffuse the flame and reduce its liability to flash back.

The last thirty years have witnessed a wonderful development of every kind of heating appliance, and the most modern gas lighting units make use of the gas for heating solid materials to incandescence instead of deriving the light from the luminosity of the flame itself.

Acetylene Gas.

Although acetylene gas was discovered in 1836 it was not until 1892 that its commercial development was made possible by Willson, who discovered a method of producing calcium carbide in large quantities. The application of acetylene to heating and power has been very recent indeed, and the use of acetylene and oxygen in the blow pipe has produced almost the highest temperature known to chemistry—a temperature approximating that of the electric arc, probably above 6,000° Fahrenheit.

Through this means welding has been successfully accomplished and several other important industrial applications have been found. Large steel bridge girders can thus be cut apart with ease. There seems to be a great field open for the oxy-acetylene flame.

Natural Gas.

The first use of natural gas in this country was probably in Fredonia, New York, in 1821, and before long it was being used in rare instances for heating purposes. In 1859, Drake drilled the first oil well, and, as natural gas was found in abundance, its use was greatly increased. At first it was only used near the wells, but from time to time some enterprising individuals would run pipes from nearby wells to their homes and villages.

At first it was used in the coal or wood stoves for cooking and heating and at the wells for power by piping it directly to the cylinders of steam engines and using its expansive force as a substitute for steam.

The waste of gas for many years was very great, no interest

being taken in making economical appliances, or even in turning the gas off when not wanted.

The first company formed exclusively for the distribution of natural gas was in 1872 in Titusville, Pennsylvania, since which time its use has become quite extended.

As a fuel, natural gas is burned in almost exactly the same way and with almost the same appliances as manufactured gas. It may be used in the ordinary gas range, hot plate, water heater, or other gas burning appliances, the only change necessary being that because of the higher pressure the gas orifices should be smaller, and because of the higher heating value less gas is necessary to produce the same results. Furthermore, the application of natural gas to coal burning installations of all kinds is very simple and, as a rule, very efficient.

The growth of the business in the last thirty years is shown by these figures from the United States Geological Survey, representing the approximate value of natural gas produced in the United States:

In 1882	$ 215,000
In 1892	14,870,714
In 1902	30,867,863
In 1909	63,206,941

Producer Gas.

Producer gas, the gas made from cheap fuels, using oxygen from the air to produce carbon monoxide, has come into prominence within the last twelve years. Although only a few scattered installations are reported as having been made in the United States prior to 1900, there are now probably two hundred or more plants together having an output of over 50,000 horse-power.

The two principal types of gas producers are the suction plant, used for small units below 300 horse-power capacity, and the pressure plant used for larger outputs. The suction plant receives its name from the fact that the engine develops its charge of gas in the producer by means of its own suction stroke. The pressure plant develops its gas under a slight pressure due to the introduction of an air and steam blast, and the gas is stored in a holder until it is required by the engine.

In Europe producer gas has been applied much more gener-

ally than in this country, but it is fast working its way into the industries here, such as glass furnaces, brick, pottery and terra-cotta kilns, lime and cement kilns, sugar-house char-kilns, silver chlorination and ore-roasting furnaces, etc. Although its use is accompanied by some dangers and disadvantages, the facts that it is the cheapest gas made per unit of heat and contains more of the energy originally in the coal than any other, and that it is possible to use very poor fuel in its production, make it a very economical gas when properly applied.

Conditions for Good Combustion.

One of the principal points to consider in the construction of heating appliances is the combustion of the gas. Efficiency, maintenance and many other important items are largely dependent on this feature. Some of the conditions for good combustion are:

(a) Complete and equal combustion of the gas must be had over every part of the burner and from every opening in the burner.

(b) Good mixing of air and gas, and equal proportion of primary air in all parts of the burner, are essential.

(c) There must be plenty of secondary air in the proximity of the burners, so that the flames will not be smothered, and good draft through the appliance to carry away the products of combustion.

(d) Flames should not impinge on cold surfaces in such a way as to cause incomplete combustion and so waste the heat and perhaps produce carbon monoxide.

(e) In those appliances where an adjustable air shutter is used, this shutter should be easily adjustable and yet should remain as adjusted. In those appliances that have a fixed air supply, the spuds should be readily accessible.

Each different form of appliance offers problems of its own, but the observance of these general conditions is important.

Development of Gas Cooking.

In the patent taken out by Mr. Winsor in 1805 for the manufacture of coal gas, we find the first recorded suggestion of the use of gas for cooking. But the actual utilization of gas for cooking was much later. Our earliest knowledge of a gas

stove is to be obtained from a magazine of the year 1825 which described it as a piece of "gas apparatus for cooking by enclosing the circle of gas flames with its reflecting cone in a cylinder of tin, from the top of which a pipe takes off the burnt air." A drawing of the burner was also given and the writer adds: "A hot-plate has been heated by the gas, and it has also been employed to heat an oven. . . . It cannot be expected to succeed, however, except in the hands of persons whose scientific knowledge enables them to employ it with safety."

For a number of years there seems to have been little done in the way of actual trial, although the geniuses of the time were thinking about it and taking out patents. It is unlikely that we shall ever know who was the first user of gas for cooking; all we know definitely about the subject being that James Sharp, of Northampton, England, demonstrated the availability of gas cooking in his own house about 1830 or 1832, and a year or two later John Barlow, of Islington, London, had an apparatus for roasting, boiling and steaming in the kitchen of his house. This consisted of a tin oven, around the four sides of which, inside near the bottom, ran a gas pipe, fitted with small burners about an inch apart; on a stand alongside the oven were two or three rings of piping with burners, and over these were placed the boilers and saucepans.

After this, inventions for cooking by gas became more numerous, although the gas range at first gained very slowly in popularity.

In 1850 James Sharp, then of Southampton, delivered a lecture entitled "Gastronomy," in the course of which he roasted before the audience thirty-four pounds of beef, fifteen pounds of mutton, and twelve pounds of pork, and boiled and steamed twenty-four pounds of mutton and codfish, four fowls, eight plum-puddings, vegetables, etc., and baked pies and tarts, the whole being done with the expenditure of 156 feet of gas.

In the following year (1851) Alexander Graham, a well-known hotel proprietor of Glasgow, exhibited in the great Exposition in London a gas cooking oven, which was fitted with luminous jets inside. Mr. Graham made and sold a limited number of cookers for hotels and restaurants, but so far the use of gas ovens for domestic purposes was practically unknown.

A stove used in Philadelphia prior to 1860 is still in existence

and forms part of the exhibition upstairs in connection with this Centenary. It has a peculiar boiling burner which consists of a piece of ⅛ inch pipe bent upwards into a sheet iron truncated cone, containing a perforated baffle plate of the same material. The upper end of the cone contained a fine wire screen covered with about ½ inch of fine gravel.

From this time on until about 1880, the history of the use of gas for cooking was an exceedingly slow development. In 1860, the *Cincinnati Gazette* said: "At present about 100 families are cooking with different kinds of gas stoves."

The development has taken a faster pace in recent years and thus has brought us to the present state of efficiency and convenience. The gas cooking range of to-day is distinguished by the following features: The flow of the hot products of combustion from the oven burners is so directed that the food is evenly cooked top and bottom in any part of the oven; air space insulation of the oven walls prevents the loss by radiation of an undue quantity of heat; adjustable air mixers on all burners permit of the complete elimination of soot; the boiling burners are so set that the placing of vessels over them does not smother the flames, or cause incomplete combustion; the boiling burners and their fixtures are easily removed by the cook for purposes of cleaning and are put in place again with equal ease, and all details are aimed to combine efficiency and convenience.

Tests of the relative heat efficiency of gas ranges have been made, but such tests have not been sufficiently standardized so that numerical statements can easily be made. Further tests are desirable, and if greater attention is given to the question of efficiency and economy, it is probable that considerable further improvement will be made by manufacturers.

Gas Water Heating.

About 1825 Robert Hicks took out a patent in England for "Heating water in baths by means of burning spirits of turpentine, or carbonetted hydrogen gas in chambers, in the bath, or in tubes pasing through or under them."

Up to about 1890 there were really no convenient and economical water heaters. Since then the instantaneous hot-water heater has been developed and this has greatly augmented the use of gas ranges, the one being a very important adjunct to the other.

Gas water heating is one of the most important of the domestic uses of gas, and it is very desirable that water heaters be tested systematically and the results of tests made public for the information of users.

Gas Room Heating.

About the year 1833 a patent was granted to one Richard Barnes for heating buildings by the combustion of gas or oil, applying the flame either externally to tubes or chambers through which currents of air were passing, or else placing the flame inside the tubes or chambers.

Peckston in his "Practical Treatise on the Manufacture of Gas," published in 1841, says: "Coal gas has of late years been applied to the heating of churches, chapels, shops, counting-houses, etc., . . . and has been found to answer the purpose intended." The stove described closely resembled the cooking stove of 1825, except that it was provided at the top with a register instead of the flue.

A form of stove now very popular in England under the name of the "Gas-fire" and consisting of lumps of incombustible material heated to a greater or less degree of incandescence by gas burners so as to resemble a coal fire, was patented by Edwards, in 1849. Seven years later, Nathan Defries was granted a patent for a similar device, the "argillaceous material" specified having fastened upon it fibres of asbestos, which, upon lighting the gas, became incandescent. This was followed three years later by a patent granted to Reece for a stove in which the asbestos back was the main feature.

In spite of the limited use of gas for fuel a company called "The Gas Fire Company" was incorporated in England in 1852. This seems to be the forerunner of the many ill-fated attempts to do a purely fuel business by artificial gas.

Room heating is now one of the common uses of illuminating gas.

The Use of Gas for Industrial Purposes.

In 1806 Mr. Josiah Pemberton exhibited various forms of gas lights in front of his factory at Birmingham. He was the first to construct a gas stove, using it for the soldering required in his button factory.

About 1840, a Scotch manufacturer by the name of Macintosh made several tons of "cemented" steel by submitting iron at a dull red heat to the action of lighting gas. The carbon for the steel was derived from the gas.

In 1857 a patent was granted for the heating of irons for laundry work by means of gas, and in 1859 a soldering apparatus for continuous soldering by means of gas was described in the *Technical Press*. This included the use of a blast worked by a foot bellows.

In an advertisement of Elsner, of Berlin, in July, 1859, it was pointed out that there was scarcely a brand of domestic work, of industry, or of business for which a gas cooking or heating apparatus could not be recommended. Thus it is evident that the use of gas for industrial purposes is not of recent origin, and that it has not been brought about through a falling off in the use of gas for lighting, due to the increased use of electricity.

At the Paris Exposition of 1867 there was exhibited singeing apparatus for use in wool works, dye works and bleaching works. Jewellers were also using gas. Plants for chemical and metallurgical purposes and laboratory ovens were also shown.

About thirty years ago what seems to us a curious method of using gas was considerably in favor. This was its use under boilers for generation of steam for engines up to about two horse-power. At the Royal Agricultural Societies Exhibition, held in 1879, several forms of such boilers were exhibited.

In 1879 the South Shields Gas Company, an English concern, gave an exhibition of over 300 appliances in which gas was to be used for other purposes than lighting.

To-day there are about one thousand practical applications of gas in the industries, and a conservative estimate places the proportion of gas sold for fuel at one-half the total sales.

Air under Pressure vs. Gas under Pressure in Industrial Appliances.

The subject of air and gas under pressure is one that is receiving considerable attention at the present time, although the field has not been as extensively explored as the others that have been described.

In England and on the Continent there are a number of com-

panies now operating to furnish gas at high pressure for private establishments as well as for the public street lamps. The result is that in Europe there has been more done with the gas under pressure than in America, while, on the other hand, America has probably made more use of the air blast with low-pressure gas. "The disadvantage of the latter for furnace heating is that the efficiency depends upon the two pressures remaining constant. Experience shows that under working conditions it is too much to expect that these will remain constant, but the main defect in air-blast burners up to quite recently has been that they were badly designed,—their mixing arrangements being inadequate. Such gas burners as those recently designed which do away with secondary air and improve the mixing of the air and gas are a great advance on previous designs."

"High-pressure gas should have a great field before it in the industrial world. It can be applied to all heating processes with efficiencies reaching in some cases at least 90 per cent. Its chief charm is its cleanliness and its simplicity; and in by far the majority of cases it compares well in cost with solid fuel."

List of the Processes in which Industrial Appliances are Used.

Some of the processes in which gas has been used in the industries are as follows:

(1) Hardening, tempering, and annealing of steel, and the heating of automatic heating machines.
(2) Melting of base and precious metals.
(3) Forging and drop forging.
(4) Welding, brazing, soldering, and rivet heating.
(5) Developing power and generating steam.
(6) Boiling liquids and melting of solids.
(7) Tire heating, and the heating of mangles and steel rolls.
(8) Heating japanning and embroidery ovens.
(9) Air tempering.
(10) Singeing of cloth.
(11) Heating branding irons.
(12) Firing china.
(13) Melting barium chloride and cyanide of potassium for hardening steels.

(14) Embossing and stamping presses.
(15) Heating muffle-furnaces, and assay work, and reducing sweeps.
(16) Heating oil tempering furnaces.
(17) Pressing irons, stoves, and machines.
(18) Heating searing iron.
(19) Matrix drying in printing.
(20) Roasting coffee and nuts, and popping corn.
(21) Sterilizing and pasteurizing.

These are a few of the many processes that might be mentioned, but they are typical as showing the wide variety of applications of illuminating gas.

Development of the Gas Engine.

The gas engine really dates from the year 1791 when John Barber patented an engine driven by gas obtained by heating wood, coal, oil, or other substance in a retort. After the gases had been cooled they passed through a pump in which they were mixed with air, to an "exploder." At the orifice of this exploder the gas was lighted, and issued, in a continuous stream of flame, against the vanes of a paddle wheel. This was not only the first gas engine but the first gas turbine, a form of machine not in existence to-day.

In 1794 Robert Street designed a pump driven by the explosion of turpentine vapor below the motor piston. In 1801 Philippe Lebon took out a patent for an engine to give alternate explosions on each side of the piston. Samuel Brown, in 1823, designed a motor to operate by atmospheric pressure in which he used an explosive gas flame to expel the air from the chamber.

In 1823 L. W. Wright patented his double-acting vertical engine combined with a governor to regulate the speed. In 1838 William Barnet suggested the compression system of gas motor. This experimental period of gas engine research may be said to have lasted for seventy years: 1791–1860. In the latter year, Lenoir of Paris produced the first practical gas engine to work rapidly and silently, with electric ignition by jump-spark.

In the years that have followed, improvement after improvement has been made until the amount of coal gas necessary to develop ignition horse-power has been reduced from 100 cubic

feet to 14 and even 12 cubic feet per hour. Only the principal steps in the development can be mentioned.

In 1861 Million proposed compression and the use of a compression or combustion chamber. In 1862 Beau de Rochas took out a descriptive patent of the compression four-stroke cycle now known as the Otto.

Otto and Langen exhibited their free-piston atmospheric engine at Paris in 1867 and in 1876 Dr. Otto brought out his famous engine with the Beau de Rochas cycle.

In 1878 and 1879 Mr. James Robson, and in 1882 Mr. Dugald Clerk, patented two-cycle engines, and in 1884 Atkinson brought out a "differential" type with the strokes of the cycle of different lengths.

In 1890, when the Otto patent expired, many firms who had been making gas engines upon other lines brought out new designs, all working on the Beau de Rochas cycle. This gave a great impetus to the sale of gas engines. With the close of the century came the utilization of producer gas for power purposes; the manufacture of large-sized units over 600 horse-power by John Cockerill Company in Belgium and by Crossley and the Premier engine in England; the design of the Westinghouse throttling governor; and the Sargeant engine with cut-off governing; the rise of the natural gas engine in large units; and the double-acting gas engine with compression in America.

The two great classes of gas engines to-day are (1) the four-cycle or "Otto" type and (2) the two-cycle or "Brayton" type. The former, called also the internal combustion type, with heating at constant *volume,* has only one working stroke in four, the four strokes being: charging, compressing, firing, exhausting.

The two-cycle type, with heating at constant *pressure,* usually has two cylinders, one a compressing pump and the other the working cylinder.

A third type of engine which should be mentioned is the cycle with heating at constant *temperature* or Carnot cycle. The nearest actual approach to this cycle using gas is the Diesel engine.

I am indebted to the Chairman of the Committee on Gas Appliances of the American Gas Institute for most of the material contained in the above sketch of the history of gas appliances.

2. THE TESTING OF GAS.

Among the industries conducted by public service companies, none has perhaps been for so long a time and in so great detail subject to legal requirements and restrictions as the gas business. The value of the service rendered by a gas company depends upon the quality, quantity, and condition of the gas delivered. Many elements besides the energy content of the gas go to determine good or poor service. These various elements are enumerated more or less completely in many of the gas ordinances now in force. These ordinances are sometimes, therefore, very technical and detailed in character; in other cases, however, containing very meagre specifications. The method of preparing such ordinances, as well as the ordinances themselves, are very various. In some cases, old ordinances, long since out of date, so far as their technical specifications are concerned, are still in use; in other cases such ordinances have been more or less extensively amended: in still other cases entirely new ordinances have been drawn to supersede the old; in many cases no regulatory ordinances of any kind have ever been adopted.

The process of adopting a new gas ordinance is often long and painful. No recognized single standard of quality, purity, and pressure has ever been set up. Indeed, the conditions are so different in different places that a single standard is impracticable. It was because the standard of performance demanded of gas companies in different cities and states is so different, and because so much difference of opinion existed among engineers and experts as to what could fairly be required of a gas company under a given set of conditions, that the Bureau of Standards took up about two years ago a careful study of the subject of state and municipal regulations of the quality, purity, and pressure of the illuminating gas supplied by gas companies.

A compilation of all the state laws and city ordinances in force in the country was first made, and their technical requirements tabulated. A detailed study was then undertaken of the various features of such laws, and an attempt made to formulate a law that should contain reasonable standards of quality, purity, and pressure of the gas, and a reasonable set of operating requirements. In this study, a large number of the best informed gas experts in the country were consulted, either personally or

by letter, and many gas plants visited by a representative of the Bureau. In this work, the Bureau has been greatly assisted by the responsible officers and members of the technical staffs of gas companies, both large and small, and by members of public service commissions, gas inspectors and consulting engineers. The Bureau has endeavored to consider all sides of the various questions involved, and has, of course, received very conflicting opinions on some questions. It has been a source of great gratification to those conducting this investigation to see the fairness and broad-minded spirit shown generally by representatives of the gas companies in discussing questions which affected them so vitally; and I wish to express on behalf of the Bureau our sincere thanks to them and to all others who have assisted us so willingly and discussed with us so frankly the many important questions involved in the work.

The results of this investigation have been recently published in one of the technical circulars of the Bureau of Standards, and it is our hope that it may be of great value both to city and state officials and to the gas industry in the preparation and revision of rules and laws controlling the distribution and sale of illuminating gas. The position of the Bureau in this matter, as in so many other, is advisory. It has no legal authority to enforce its conclusions, and no disposition to suggest federal legislation or regulation. It acts as an unbiased co-ordinating agency, to formulate the consensus of opinion of those best qualified to express opinions, on technical questions of great practical importance. If the work be well done, it will carry great weight; otherwise, very little.

A second investigation is in progress, and will be embodied in a separate publication. It will have to do with the methods and instruments employed in testing gas for its heating value, its photometric value, and its chemical purity, as well as in testing meters and measuring gas pressures. This will be designed to assist gas inspectors and engineers in determining whether the gas meets the specifications under which it is sold. A large amount of experimental work is being done at the Bureau, in testing methods and instruments, and in some cases improving both methods and instruments, and the results of this work will be ready for publication, it is hoped, some time within a year. This circular will be much more comprehensive than the " Notifi-

cation of the Gas Referees of the City of London." The latter is accepted as authoritative not only in London but also elsewhere, to some extent even in the United States. It is hoped that the publications of the Bureau of Standards on gas testing may come to be regarded as authoritative and may prove to be of real value to the gas industry. To this end the Bureau is carefully studying the various questions involved, and seeking advice and information from many sources.

Candle-power Measurements.

The cande-power of a gas refers to the candle-power of a luminous flame as the gas issues from a specified burner at the rate of 5 cubic feet per hour. This is measured by comparison with some kind of flame standard, candles being the most used but least reliable standard. The pentane lamp is probably the best flame standard in use, in spite of its serious limitations. Oil lamps may be used safely if only moderate precision is required, provided they are frequently calibrated and used with care. But inasmuch as mantle lamps are so largely employed in lighting, and a high candle-power gas is not necessary for them, less importance attaches to photometric tests for bare gas flames than formerly, and less stringent requirements may be made as to the candle-power of the gas so measured. It is thus possible to obtain a given heat value and a better lighting service when using mantles at an appreciably smaller cost of manufacture of the gas. But although the photometric testing of gas is less important than formerly, the photometric testing of gas mantles and of other lighting appliances is more important than heretofore. The gas company can do much good by encouraging the use of good appliances, and many of the larger companies have adopted very progressive methods in this respect. The public needs information as to the best use of light (both gas and electric) in homes, in stores and factories, in public buildings and on the streets, and the lighting companies can do much good in this direction.

Tests of Gas Appliances for Heating, Cooking, and Industrial Uses.

An immense variety of gas appliances are used for household and industrial purposes, and here again the gas company can

do much good by encouraging the best and safest, and setting a high standard in the matter of connecting such appliances. The committees of the American Gas Institute and the National Commercial Gas Association on gas appliances have done excellent work in this direction, and no doubt will continue even more actively than in the past. The standardizing and testing of such appliances and materials used in connecting them, and the careful determination of their efficiency and performance, are quite as important and practicable as the measurement of the efficiency of gas burners or mantles.

Tests for Impurities.

It is very important to have the gas free from such impurities as sulphur compounds and ammonia, and tests and penalties are usually prescribed to insure reasonable freedom from such impurities. Gas companies find it to their advantage to comply with such requirements, the tests are easily made, and they offer comparatively little trouble in the administration of the law. It would be desirable and to the interest of the gas companies, if still greater freedom from these impurities could be economically attained.

Gas Pressures.

One of the most important features of good gas service is a nearly uniform pressure, neither too small nor too great, and yet the tendency is toward higher pressures. It is also one of the most difficult conditions to meet, as is likewise the case in the distribution of electricity for lighting purposes. In both cases, heavy mains, feeders, boosters, and storage tanks or batteries are or may be employed to aid in maintaining steady pressures. But whereas the gas company enjoys an immense advantage over the electric company in its gas holders, it suffers a disadvantage due to the clogging of service pipes, and sometimes to differences in altitude of different parts of a city. Heating as well as lighting appliances require adjustment to suit the pressure, and after such adjustment has been made serious variations of pressure are detrimental to efficiency, and may even be dangerous. Hence pressure limits are set in regulatory ordinances, and measuring the pressures at various parts of a city is one of the duties of a gas inspector.

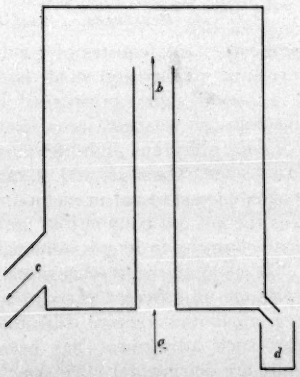
3. THE MEASUREMENT OF THE HEATING VALUE OF A GAS.

Gas is used for the production of heat, light, and power. For heat and power, and largely for lighting as well, its value is determined by the amount of energy it contains, and by its condition as respects pressure and purity. Its energy is measured by burning samples of the gas in a calorimeter. For this purpose, several different forms of instruments are available. The able Committee on Calorimetry of the American Gas Institute has done very valuable work in testing different forms of calorimeters, and in showing how they may be used in giving reliable results. The Bureau of Standards has also been making a thorough experimental study of gas calorimeters, the results of which will be published in the Bulletin of the Bureau. The results of this work will enable still higher accuracy to be attained in calorimetric work.

The Gross and Net Heat.

A gas calorimeter is an instrument for measuring the heat of combustion of a gas. In the usual type of instrument, the

FIG. 1.



gas to be burned and the air to support combustion are admitted to the calorimeter at room temperature, while the products of combustion are cooled substantially to room temperature before

escaping, these products all being gaseous except that a certain amount of water vapor is condensed and collected as water at room temperature. The heat measured by the calorimeter under these conditions is called the *gross* heating value of the gas.

If the heat of condensation at room temperature of the water vapor condensed and collected is subtracted from the gross heating value, the remainder is called the *net* heating value. Usually the gross heating value is specified in city ordinances and in rules of the State Commissions (where a calorimetric test is required) and it is commonly believed (though erroneously) that it can be as accurately measured as the net value. As there is some confusion on this point, and as the measurement of the heat of combustion of gas is a very fundamental problem, I may be permitted to discuss the question rather fully. In the figure, representing diagrammatically a calorimeter, the air current entering and leaving the calorimeter is indicated by arrows, while the water vapor content of the air is indicated by letters.

a = mass of water vapor *admitted* to the calorimeter (per unit quantity of gas burned) in the incoming current of air.

b = mass of water vapor *formed* by the combustion of unit quantity of gas.

c = mass of water vapor *escaping* (per unit of gas burned) with the products of combustion.

d = mass of water vapor *condensed* in the calorimeter and collected outside.

Let A = latent heat contained in a.
B = latent heat contained in b.
C = latent heat contained in c.
D = heat of condensation at room temperature of d.

The Total Heat.

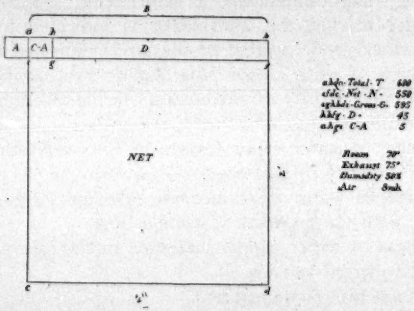
We will define the *total* heat T as the amount of heat measured by the calorimeter per unit quantity of gas burned if the air (admitted to the calorimeter at room temperature) is dry and if the water vapor formed by combustion is all condensed in the calorimeter, and both it and the products of combustion escape at room temperature. In other words, when gas is burned in dry air at room temperature, and the total products of combustion are cooled to room temperature, and all water vapor

formed is condensed to water, the total heat given up in the process is called the *total heat*. Then, under these circumstances,

$$a = o$$
$$c = o$$
$$b = d$$

and the heat measured by the calorimeter is the total heat T. This would be the value found if the measurement were made with a bomb calorimeter. This is a larger quantity than the *gross heat* defined above, due to the fact that usually more uncondensed water vapor escapes from the calorimeter than enters with the incoming air. If the products of combustion

FIG. 2a.



carry away water vapor of mass c and latent heat C, the heat measured will be $T - C$. If the air entering contains water vapor of mass a and latent heat A, then the heat measured will be $T - C + A$. But this is defined to be the *gross heating* value, G. Hence

$$G = T - C + A.$$

The net heating value N is the gross minus the heat of condensation D of the water deposited per unit of gas burned, d. Hence

$$N = G - D = T - C + A - D.$$
$$= T - (C + D - A).$$

But since $a + b = c + d$

and $A + B = C + D$

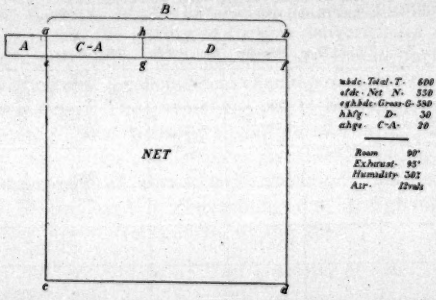
$C + D - A = B$

and therefore $N = T - B.$

$N = T - B.$

That is, the net heating value of a gas is the total heating value (as defined above) minus the latent heat of all the water vapor *produced by combustion.* Both the *total heat* and the *net heat* are independent of the amount of water vapor entering the calorimeter with the incoming air current or of the quantity of water vapor leaving with the products of combustion. That is to say,

FIG. 2*b*.

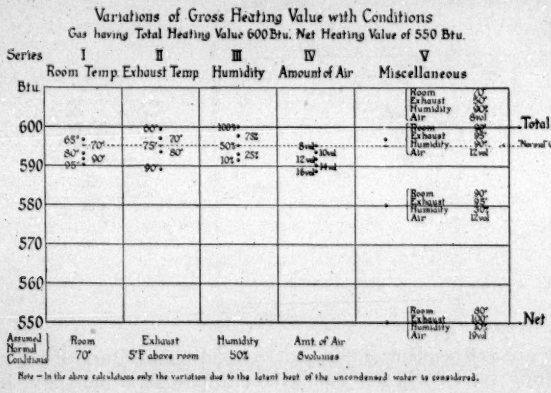


they are independent of the quantity and temperature of the air entering the calorimeter and of the atmospheric humidity, but depend only on the quality of the gas burned. The gross heat, on the contrary, varies with *a*, being a maximum when the atmosphere is saturated, and a minimum when it is dry. It also varies with *c*, being larger as *c* is smaller and vice versa. That is, the gross value varies with the atmospheric humidity and with the quantity and temperature of the gaseous products leaving the calorimeter. If the air enters dry and is great enough in quantity to carry away all the moisture produced by the flame, so that $d = o$, then the gross and net values are equal. If the air enters saturated, $a = c$ and $b = d$, and the total and gross values are equal.

Gross Heat Affected by Atmospheric Conditions.

Hence we see that the *total heat* and the *net heat* depend only on the gas itself, and are wholly independent of the condition of the atmosphere and of the quantity of air passing through the calorimeter (if there is enough air to insure perfect combustion). The *gross heat,* however, is a variable quantity, depending on both these factors as well as upon the gas itself. If, for example, a certain gas has a total heat of 600 B.t.u. and a net heat of 550 B.t.u. the gross heat as measured by a calorimeter may be anywhere from 550 to 600 (or may be outside these limits in extreme

FIG. 3.



cases) according to the temperature and the atmospheric humidity at the time of the measurement and the quantity of air passing through the calorimeter.

It will be seen from the above that the net heating value is a truer measure of the quality of the gas than the gross. It is the gross value, however, which is used generally as a test of the quality of the gas. Hence, even if the calorimetric work be correct to within one per cent. (and the net heat determined within one per cent.) the result may be in error by several per cent. if the gross value is used. Since the object of the work

is to test the quality of the gas, the result should, of course, be independent of the state of the weather.

The effect of atmospheric moisture upon the light of a gas flame is even greater than its effect upon the results of a calorimetric measurement, but this effect is substantially eliminated in photometric testing if a flame standard is employed. The candle-power of a flame is greater in a drier atmosphere, being about 10 per cent. greater for a pentane of Hefner lamp in a dry winter atmosphere than in a moist summer atmosphere. The gas flame changes also, probably about the same amount, so that a photometric measurement of a gas flame against a flame standard does not give the real candle-power of the gas at the time, but does give a measure of what that candle-power would be if the flame were burning in an atmosphere of average humidity. This is as it should be, for the object of the photometric measurement is to test the quality of the gas delivered, for which the company is responsible. The gas company should obviously not be held responsible for changes in candle-power due to the atmospheric moisture. Thus, while the actual candle-power and the gross heating value both vary considerably with atmospheric humidity, the *relative* candle-power and the *net* heating value are both independent of atmospheric conditions, and hence may properly be employed in determining the light-giving and the heat-giving power, respectively, of the gas.

Specification of Unit Quantity of Gas.

In the foregoing discussion, the heating value of a gas has been expressed as the heat produced per *unit quantity of gas burned*. This unit as commonly employed is the cubic foot of gas at a normal barometric pressure of 30 inches of mercury, at a temperature of 60° F., and saturated with water vapor at this temperature. That is to say, if the gas is measured by a correct wet meter (containing water only) at 60° F., and normal barometric pressure, there will be no correction to apply to the meter reading. Under these circumstances, the gas will contain nearly 2 per cent. of water vapor, which is taken as normal. If, however, the temperature is higher and the barometer is lower, a cubic foot of gas will have a less energy content, that is to say, a smaller heat value, for three reasons, viz.: (1) because of the higher temperature, (2) because of the lower pressure, both of

which decrease the density; and (3) because of the greater vapor pressure of water at the higher temperature, a greater percentage of the volume being occupied by water vapor. Hence, the heat produced in the calorimeter per cubic foot registered by the meter will be less; at 29 inches pressure and 90° F., it will be 11.5 per cent. less. This correction can easily be taken from tables prepared for the purpose, in which usually the first and third corrections are combined in one. (One is apt to infer from the descriptions often given that the correction for varying vapor pressure is not made, because it is not mentioned explicitly. Indeed, some tables do not take account of this.)

Effect of Barometric Pressure and Temperature.

These corrections enable one to determine from the calorimeter measurement the true net heating value of a cubic foot of the gas under normal conditions of temperature and pressure, and this is a measure of the quality of the gas. But the company delivers to its customers gas measured at actual existing barometric pressures, and no correction is made to the meter readings for variations in barometric pressures. The fluctuations above and below the mean barometric pressure in any given place may be ignored, inasmuch as they will balance out in the long run. But if the mean barometric pressure is below 30 inches the customer gets a less quantity of gas on that account, for the density and heating value are less in the same proportion as the barometric pressure is less than 30 inches. For example, Minneapolis is about 800 feet above sea level and has a mean barometric pressure of 29.2 inches more than 2 per cent. less than normal. Denver is 5,300 feet above sea level and has a mean barometric pressure of 24.7 inches, 17.7 per cent. less than 30 inches. Hence gas that shows 600 B.t.u. as tested in Minneapolis (*i.e.*, reduced to 30 inches) would give only 584 B.t.u. if reduced to the mean pressure at which the customer gets it. In Denver, gas that shows 600 B.t.u. by calorimetric test (*i.e.*, reduced to 30 inches) gives only 494 B.t.u. at the pressure at which it is delivered to the company's customers. In Boston, New York, Philadelphia, and all cities at or near sea level, the mean barometric pressure is practically 30 inches and the present practice is perfectly correct. This suggests the obvious fact that either the heat value should be calculated for the mean barometric pressure at which the gas

is delivered to the users at any given place, or the meter readings should be corrected to normal barometric pressure. The latter would, of course, be very laborious in practice unless the meters were set so as to do this automatically.

The same remark applies, of course, to the temperature. Tests are reduced to 60° F., and if this is the mean temperature of the meter, no temperature correction is necessary to the meter readings. The mean annual *outdoor* temperatures of Boston, New York, Chicago, Denver, and Seattle differ by only a few degrees (averaging about 50° F.), so that there is probably very little difference in the average meter temperatures in the cities of the northern portions of the United States. New Orleans has an average temperature 20° higher, and hence there may be several per cent. less average heat value of the gas per cubic foot as delivered and metered to the customers in New Orleans, due to this cause alone. Buffalo and Minneapolis have somewhat lower mean temperatures than the average, and this tends to offset the effect of their lower barometer.

Two Aspects of a Calorimeter Test.

We see, therefore, that a calorimetric test of gas may be regarded from two different points of view. According to the first, the test gives the heat value of the gas per cubic foot *measured under standard conditions of temperature, pressure, and water vapor content.* The total or net value of this heat depends only on the composition of the gas, and could be calculated if we knew its chemical composition. The gross value as usually measured and defined depends to some extent on the atmospheric conditions and other circumstances of the test, and it is not as true a measure of the quality of the gas as the net heat.

According to the second point of view, the calorimetric test should give the heat value of a cubic foot of the gas as nearly as possible *as delivered to the customer,* and hence the correction for temperature and pressure should be, not to 60° F. and 30 inches barometric pressure, but to mean annual meter temperature and pressure of the city where the gas is sold. Then if a uniform heat value were required, the gas would be made of enough higher heating quality in a city of higher altitude or higher mean temperature than the average to offset the effect of smaller

density. This would seem perfectly feasible except possibly for cities at high altitudes, where the difference is large, and here it may be better to make the correction either in the rate of the meter or the heat value required.

It may be urged that such corrections tend to complicate the sale and distribution of gas, and that the present methods are good enough in these particulars to be let alone. But I think this is not a correct view. What is the logic of trying to keep meters free from accidental errors greater than 2 per cent. and of trying to make calorimeter determinations correct to 1 or 2 per cent. if constant errors of 2 to 5 or even 10 to 15 per cent., or more, due to low barometer or to a higher or lower mean temperature than the average, are ignored?

To use an expensive calorimetric outfit in order to make the calorimetric determination accurate to a high degree is commendable. But to correct the result to 30 inches barometric pressure when the gas is burned in the calorimetric (and delivered to the customers) at an average pressure of say 29.2 inches as in Chicago or Minneapolis, or 24.7 inches as in Denver, is not in harmony with the accuracy of the experimental work.

I would not, of course, suggest that in all routine calorimetric measurements an attempt be made always to apply all possible corrections; but there should be a well formulated official specification such that a given mass of gas of a given quality tested by different persons would be found to give the same heat value (within reasonable limits to cover the errors of measurement); and, also, a given mass of gas tested by the same person and the same instrument, but under varying conditions of temperature, pressure, and atmospheric humidity, should give the same heat value.

Distinction between Volume and Quantity or Mass.

The cost of manufacturing gas is determined not by the volume the gas occupies after it is made, but by the *mass* of the gas and its quality; and, similarly, the value of the gas to the user is determined by the *mass* of the gas and its quality. A calorimetric determination under present methods tests the quality, the meter measures its volume, and no account is made of variations in density. As already stated, the fluctuations of atmospheric pressure above and below the mean may be ignored;

but the departure of the mean from the normal may be considerable, sometimes amounting to several per cent., and representing large sums of money in a large city.

A parallel case exists in the testing of coal for the purpose of calculating its value on a heat unit basis. The value of a cargo of a given kind of coal depends on two things: its total weight, and the average number of heat units yielded per pound of coal. In taking a sample for calorimetric test care is always exercised to get a representative sample, which is then sealed to prevent any change in moisture content, or other change. If the sample is dried before burning, the percentage of moisture is recorded, and the heat of combustion measured is reduced by the percentage of moisture so as to give the average heat value per pound of the coal as weighed on delivery. To dry the sample and burn it in a calorimeter, and report the heat value per pound of dry coal, and say nothing about the moisture content, would obviously be misleading. But if the moist coal is burned in the calorimeter, the heat per pound of the coal as weighed is directly determined and no separate determination or record of the moisture in the coal need be made.

To return now to the case of gas testing, it is seen that to measure the heat value of the gas per cubic foot under the condition in which it passes through the consumers' meters is what is really wanted. Of course, it is impossible to test the gas at each meter, hence the most that is practicable is to reduce the result not to 60° F. and 30 inches barometric pressure, but to the mean meter temperature and mean barometric pressure of the city where the gas is distributed. Such mean temperature and mean pressure are not difficult to determine at least approximately, and it would appear not impracticable to carry out such a method. In order to illustrate, in a concrete way, how the gross heating value as usually defined and measured varies under different conditions, the *total* and *net* heat being always the same for the same gas, I shall give a number of numerical examples. In each case suppose the same mass of gas is taken, the composition being such that 600 heat units for the total heat are given off, and 550 net, when one cubic foot of gas at 30 inches barometric pressure and 60° F. (saturated at that temperature) is burned.

In Fig. 2 the rectangle *a b c d* represents the total heat, 600 B.t.u. The rectangle *a b e f* represents the heat of condensation, *B*, of the whole amount of water vapor formed in the flame, and *h g b f* is the part, *D*, represented by the water vapor condensed and collected. Hence *e f c d* is the *net* heat, *N*, and *c e g h b d* is the gross heat $N + D$. When the room temperature is 90° F., exhaust 95°, humidity 30 per cent., and air passing is 12 volumes, the gross heat is 580 B.t.u. If room temperature is 70°, exhaust 75°, humidity 50 per cent., and 8 air volumes are used, the gross is 595 B.t.u.

Fig. 3 shows the values of the gross heat at various temperatures, humidities, etc. In extreme cases, possible to realize but not likely in ordinary practice, the gross may be higher than the total or nearly as low as the net. A variation of 10 or 15 B.t.u. is, however, liable to occur even in the most careful work, due to varying atmospheric conditions.

The "Normal" Gross vs. the Net.

The above examples show that gas of a total heating value of 600 B.t.u. and of a net heating value of 550 B.t.u. *may* have a gross value anywhere between 550 and 600 according to the condition of the atmosphere and the rate at which air passes through the calorimeter, although under usual conditions the variation is relatively small. It is true, of course, that a wide range of gross value would probably never occur in any one place. Nevertheless, the specifications for taking the heat value of a gas should be so definite that the same result (within the inevitable errors of observation) would be obtained on a damp or dry day, in summer or winter. This will be true if the net value be specified, or if the gross value be specified under certain normal atmospheric conditions and a normal rate of flow of air. This would necessitate applying corrections for variations in the atmospheric humidity and for variation in the rate of flow of air, which latter is difficult to measure. Without such specifications the variations due to the atmosphere may be much more than the usual errors of the instrument except under uniform external conditions. In much of the best calorimetric work published, where very close agreement in different determinations has been found, the atmospheric conditions have been very uni-

form. If work done at different times shows different heat values, the difference is attributed to the difference in the gas. At the Bureau of Standards atmospheric differences have been made intentionally and the differences in the gross heat appeared at once.

It is very difficult indeed to measure the quantity of air flowing through a calorimeter, and if one varies the position of the calorimeter damper the rate of flow of air varies considerably. It may be possible to determine approximately by careful investigation the quantity of air passing through a calorimeter for a given rate of burning of a given gas, and so fix a basis for correcting the gross heat to a normal gross. Instead of attempting to specify the rate of flow of the air it is more usual to operate the calorimeter so as to obtain the highest gross value possible. But the maximum value will vary under different atmospheric conditions. Sprinkling the floor of the calorimeter room to raise the humidity and decrease the temperature of the atmosphere will increase the gross heat; raising the temperature of the room without such sprinkling will lower it. But neither operation would have any effect on the net value.

If instead of correcting the variable gross value to a constant "normal" gross we specify the total heat as defined above, we must correct the measured gross by adding C — A. That is, we must add the difference in the latent heat of the water vapor leaving the calorimeter and that entering it. This also requires a knowledge of the atmospheric humidity and the quantity of air passing through the calorimeter, and hence is not an easy correction to apply.

If, however, we specify the *net heat* of the gas, we require no knowledge of the atmospheric humidity or the quantity of air entering the calorimeter. We must, of course, have enough air to insure complete combustion, but an excess does little harm. For while an excess decreases the gross value measured, it also decreases by the same amount the correction D subtracted from it, thus leaving a constant difference, the net heat, *the only quantity that can be readily measured unaffected by atmospheric conditions.*

(No argument is here made for the net heat because some of the gross heat of the gas is not utilized in ordinary gas appliances.)

Shall the Actual Net Heat be Substituted for the Gross?

If it is granted in view of the above consideration that the net heat is the proper quantity to specify as indicating the quality of the gas, the practical difficulty remains that in many ordinances and rules a gross value of 600 B.t.u. is now specified, and it is difficult to change established practice. Even if a change could be readily made, 600 B.t.u. sounds better than 550 and some feel that the latter figure does not give the gas manufacturers credit for all the heat they have put into the gas. This difficulty, and the practical difficulty of changing established rules, can be largely overcome by allowing the gross value of 600, or the corresponding total, to remain in the rules and ordinances, but to add by way of amendment that *for purposes of test* 550 B.t.u. net (or whatever is found to be equivalent) shall be construed as equivalent to 600 gross. This would give at once a fixed standard, more satisfactory than the present gross or even a normal gross, and would at once remove one of the most serious objections to the present practice of gas calorimetry. To correct the measured net heat to the mean annual meter temperature and mean annual barometric pressure of the city where the gas is distributed, instead of to 60° F. and 30 inches barometric pressure (or to omit the correction for barometric pressure altogether), would be the next logical step in putting the calorimetric testing of gas on a more scientific and likewise a more businesslike basis. These two changes are, however, too important and too far reaching to expect that they could be agreed to and put into practice immediately. I suggest that a committee of the American Gas Institute working in co-operation with the Bureau of Standards might give the matter careful study, and report their findings to the Institute and the public. I believe that the Institute and the gas interests at large would favor the adoption of such changes in practice if on careful study they appeared to be just and practicable. To do so would be in harmony with the present tendency to adopt uniform standards of gas quality, so that 1,000 cubic feet of gas would mean the same thing, in actual service as nearly as possible in different places. No criticism is intended that such changes have not been adopted before. But now that instruments are more accu-

rate and methods more perfect and requirements more exacting than ever before, we should be as careful in taking account of the varying density of the gas as we are in measuring its volume and quality.

The Bureau of Standards has not suggested these changes in current practice in its recent publication, but in the next publication on testing methods these questions will arise, and in studying them we shall hope for as cordial coöperation from the gas interests as they have given us in the first investigation.

The Automatic Sprinkler. ANON. (*Amer. Mach.*, xxxvi, 16, 642.)—*Insurance Engineering* considers that the automatic sprinkler is the greatest single factor of conservation in the industrial world to-day. There are certain classes of factories that could not endure without the protection afforded by this device, and it should be made compulsory by law to install this protection in all buildings of combustible or otherwise unsafe construction and arrangement where people congregate, whether by compulsion or of their own volition.

Lubricating with Turpentine. F. J. BADGE. (*Amer. Mach.*, xxxvi, 13, 497.)—Mr. Badge finds that lubrication with turpentine for drilling hard steel, such as spring-tempered steel, raised the production at least 40 times above that when no lubricant was used. An editorial note adds that a mixture half turpentine and half spirits of camphor is a good cutting compound. Nitric acid is used as a lubricant for turning tempered steel, but care should be taken that nitric acid does not get into the eyes.

Formation of Hydrogen Peroxide under the Electric Discharge. A. BESSON. (*Comptes Rendus*, cliii, 877.)—The discharge chamber was cooled to several degrees below zero and the pressure varied from 30 to 760 mm. The test used for hydrogen peroxide was the blue color obtained with chromic anhydride, as the presence of ozone will also produce a blue color with potassium iodide. With water vapor alone no hydrogen peroxide was found. In oxygen and water vapor it was always found, except at extremely low pressure; it was particularly strong in an excess of oxygen at pressures from one-half to one atmosphere. In air and water vapor it was difficult to prove its formation, probably owing to the action of nitrogen oxides. The strongest test was found in an excess of air. As the conditions of cooling, low pressure, and excess of oxygen occur at high altitudes, it is believed that the appearance of hydrogen peroxide in rain is due to electrical phenomena in air.

Radium Content of the Waters at Bath. SIR W. RAMSAY. (*Times*, March 12, 1912.)—The recorded analyses of the Bath waters showed in the main merely ordinary constituents, most of which are present in many drinking waters, and, so far as was indicated by the analyses made at the *Lancet* laboratory, the only unusual constituents were small quantities of strontium and lithium with a trace of bromine. But the fact that many mineral waters all over Europe had for ages past been used for curative purposes, combined with present knowledge that such waters, while of a not unusual "chemical" composition, all agreed in yielding helium, made it interesting to examine the Bath waters for radium and for niton, the emanation of radium. In 24 hours the King's Well gave off 4.927 litres of gas, containing, in 10,000 parts, 360 of carbon dioxide and 9,640 of nitrogen, etc., including 73.63 parts of argon, 23.34 of neon, and 2.97 of helium. In the water of the King's Well there were 0.1389 mg. of radium per million litres. If the niton was represented by the weight of radium capable of forming the niton present in a million litres of water or gas, the figures of the water of the King's Well, the Cross Bath, and the Helting Bath were, respectively, 1.73, 1.19, and 1.70, and for the gas from the King's Well 33.65. The water from the Hospital Natural Baths and from the Crescent Pump Room at Buxton were found by Dr. Makower each to contain 0.83 mg. per million litres, so that the waters from the King's Well and the Helting Bath were more than twice as rich in niton. The Gentlemen's Natural Baths at Buxton contained 1.1 mg. per million litres, or about the amount in the Cross Bath. The gas from the King's Well at Bath contained about four times as much as was contained in the natural gas from Buxton, *viz.*, 7.7 and 8.5 mg. per million litres. It was, unfortunately, impossible to compare these amounts with statements of the radio-activity of foreign waters, for the latter were stated in uncertain units.

The Variation of the Conductivity of a Phosphorescent Body under the Influence of Light. P. VAILLANT. (*Mon. Sci.*, ii, 842, 137.)—The substance observed was calcium sulphide. One of the effects of the current is to polarize the resistance. This polarization is produced slowly, but is very persistent. Another noticeable circumstance is that the resistance of the sulphide increases continuously, independently of all radiation. But the variations in conductivity have no effect on the relative variations which determine the radiant energy. The increase of conductivity which determines the radiant energy is not instantaneous, and three periods can be distinguished in the total variations resulting from a luminosity of given duration and intensity: first, a period of luminosity; second, a period during which the conductivity continues to increase, although luminosity has ceased; third, the period of the decrease of conductivity.

GAS AS AN ILLUMINANT.[1]

BY

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THIS paper is divided into two parts: first, that treating briefly of the historical subject of lighting, and, second, a brief review of the art as known to-day. Attention is entirely devoted to the subject of ordinary gas, as time will not permit of a consideration of special gases, such as Pintsch, carburetted-air, acetylene, etc.

HISTORICAL.

Until the introduction of gas as an illuminant in the early part of the nineteenth century, but little progress had been made in the art of lighting, from the earliest prehistoric days down to that time. The most notable advances so far made had been in the introduction of the sperm candle and the use of the Argand burner with oil lamps. With the introduction of gas, however, a vast stride forward was taken which far outranked all other progress which had so far been made in the art of artificial lighting. In order to appreciate the importance of this discovery it may be well to briefly review the history of lighting up to that time.

The beginnings of artificial illumination go back to the earliest prehistoric days, for when man first made fire he had light, and the old camp fire not only served to cook the simple meal, furnish warmth for the savage, and keep away the wild beasts, but it also gave him sufficient illumination to meet all the necessary requirements of the time. For many centuries burning wood continued to be the only means of lighting; from the bonfire developed the firebrand and the pine torch. Even

[1] Address delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant, under the auspices of The American Philosophical Society, The Franklin Institute, The American Chemical Society and The American Gas Institute, in the hall of The Franklin Institute, Philadelphia, on Friday, April 19, 1912.

as late as the days of Homer, the Greeks knew no other light than that of the flaming torch of pine wood. The tourist to-day will still meet in many far-away country houses, for instance in northern Bohemia and in some Alpine districts, torch-holders close to the fireplace for holding the torch. During the long, dull evenings the peasant's hut is lighted only by these crude torches, hewn from pine logs. This form of lighting was used extensively as late as the year 1000, and was frequently provided with a hood and even a chimney for carrying off the smoke.

Going back, however, to a very early period, we find the first step away from the pine torch. Man had begun to recognize the luminous power of animal and vegetable fat. First, tallow was burned in open dishes. This method of lighting was neither bright nor agreeable, but sheep's and ox's tallow were easily had, and represent the first use of fat for lighting purposes. Later a cotton wick was inserted in the fat or tallow, and we find in the numerous collections of Roman lamps many examples of beautifully chased and carved forms with one or more openings through which the wick protruded. At best, however, the illumination from such a form of oil lamp must have been extremely poor, as judged from modern standards.

The next step in the progress of lighting was the invention of the candle. As early as the beginning of the fourth century, under the government of the Emperor Constantinus, the city of Byzantium is said to have been illuminated with candles on Christmas Eve. No further steps forward, however, were made for many centuries, and even at the end of the eighteenth century tallow and wax candles were made with plain cotton wicks. The greatest drawback to the old-fashioned candle was the fact that the wicks required constant trimming. How modest the demands of our forefathers were is evident from the words of Goethe, saying that he cannot imagine any better invention than that of candles, which would burn without being trimmed.

Another inconvenience of candles was that the fire to light them had each time to be struck with steel and flint, as matches are an invention of the nineteenth century. For obtaining a flame from sparks, wooden sticks with sulphur and chlorate of potassium at one end were invented. To ignite these sticks it was necessary to dip them into sulphuric acid, which, therefore, must always be kept handy. How surprising this invention

was to the people of that age is evident from a sentence in Grillparzer's Autobiography, "As often as I take hold of a chemical lighter, a feeling of gratitude overwhelms me, thinking of the time when at night I have tried to strike a light with flint and steel."

The first part of the nineteenth century witnessed a great change in candle manufacture; namely, the introduction of the method of casting instead of that of dipping. This made a much neater candle. The inconvenience of having to trim the candle has been recently done away with by the discovery of the use of boric acid, into which the wicks are dipped. These wicks are plaited with three strands, which spread a little as they burn away, and therefore reach into the hottest part of the flame, where they burn to ashes. By the time the candle had reached this stage of perfection, however, it had long been outrivalled by other means of lighting—first by oil lamps, and then by gas and electricity.

Until the latter half of the eighteenth century little or no change in oil lamps had been made from the shallow vessel with its wick and smoky flame. The oil lamp of Goethe's age differed in principle in nothing from those which have been found at the excavations of Herculaneum and Pompeii. They were very simple: an oil tank with a cotton wick. The greatest trouble with such a lamp was the smoke. In order to provide a sufficient supply of air and prevent smoking, a lamp glass was placed over the flame, a very simple arrangement, but long in coming. In the works of Leonardo da Vinci, who occupied himself, besides his art, with all kinds of engineering and practical problems, we find the plan of a lamp with a glass shade, and probably also a lamp shade, but, so far as we are aware, the plan was never executed. Later the Chevalier Grollier de Severiere designed, in 1675, an oil lamp with wick and smoke exhaust tube, which was intended to both light and heat the study, in which the lamp was placed on a table. Real lamp glasses were invented in 1756 by a Parisian apothecary, Quinquet. Later on a tinsmith in Weisbaden invented the improvement of the constricted lamp glass, by which the whole supply of air is forced into the flame.

In 1784 Argand invented his famous burner, consisting of two concentric tubes, between which was placed a tubular wick.

The inner tube was hollow and permitted a current of air to pass upward, thus supplying the flame with sufficient oxygen for good combustion. A chimney was placed outside, which protected the flame, added to its steadiness, and increased its efficiency.

Early oil lamps cast annoying shadows, due to the fact that the oil had to be kept at the same level as the top of the wick. To overcome this the Carcel lamp was invented, in which the oil was raised to the flame by means of a small pump. Then followed the moderator lamps, in which the oil was raised by means of a special spring. But the entire lamp industry was changed when, after the discovery of petroleum, a thin liquid fuel was used in place of thick oil. In a very short time petroleum replaced almost entirely both candles and heavy oil lamps for general lighting. The petroleum lamp, therefore, represents the climax in lighting by a self-contained light; that is, a light which is supplied and kept by the individual. It is interesting to note, however, that, despite the introduction and use of both gas and electricity, the consumption of both candles and oil lamps is greater to-day than it ever was before.

The introduction of lighting in a community which could be supplied and operated from a central source, with nothing for the individual to do but to turn on the light when he wanted to use it, marks, up to that time, the greatest era in all the history of artificial illumination. It is the advent of this era, one hundred years ago, that we are celebrating at this time. It must not be supposed that the first gas light was made or used only a hundred years ago, but the year 1812 marks the time when the first gas company for supplying the public received its charter and started operations. Prior to that time a number of individuals had experimented with gas lights very successfully. The best known of these are Murdock, Lebon, and Winsor.

In 1792 William Murdock lighted up his home at Redruth, in Cornwall, with coal gas. Being very busy with other things at the time, he dropped the matter until 1797, when he again took up his experiments and lighted his house and office in Old Cumnock, in Ayrshire. The following year, 1798, he lighted Soho Foundry, at Birmingham, in the same way, and from this time on devoted much time to improving his methods of manufacturing and purifying the gas, until in 1802 he gave a public

display of gas lighting at Soho, which attracted much attention.

Meanwhile, in 1801, Lebon, in Paris, had lighted his house and gardens in the Rue St. Dominique with gas. In 1803 Winsor carried Lebon's ideas over to London and began to experiment with Lebon's gas apparatus at Hyde Park. The following year he obtained the first English patent for a gas-manufacturing plant, and the same year gave a public display of his gas lights at the Lyceum Theatre, London.

The year 1805 witnessed two important lighting installations—that at the factory of Mr. Henry Lodge, near Halifax, which was installed by Samuel Clegg; and that at the cotton mill of Messrs. Phillips & Lee, at Manchester. The latter was installed by Murdock and comprised nine hundred burners. Shortly after this, David Melville began experiments in this country, lighting his house at Newport, R. I., and taking out the first American patent for coal gas manufacture. In 1807 Pall Mall was lighted by gas, this being the first important installation of out-door gas lights. In 1812 a royal charter was granted to the London and Westminster Gas Light and Coke Company, this being the first gas company formed. In 1816 the first gas company in the United States was incorporated at Baltimore. From this time on the introduction of gas into the different cities of the world was rapid, but their history need not be taken up here further.

BURNERS.

The first burner as used by Murdock consisted of a small iron tube, open at the end. It was very evident, however, that this was both wasteful and smoky, and for it he substituted a closed tube, in which were bored three small holes, giving three divergent jets. This, due to its shape, was called a cockspur burner. It gave less than one candle-power per cubic foot of gas. This, however, was soon followed by the batswing burner, consisting of a thin slot in a convex tip, giving a broad but not high flame. In 1820 the fishtail burner was invented by Neilson, of Glasgow. This consisted of a concave tip in which were bored two holes at angles of about 45 degrees, so that the streams of gas issuing from these holes impinged on each other, forming a flat flame, much less broad than the batswing, but considerably higher. When used with enclosing glassware

this was found to be much less likely to crack the same. Both of these forms of burners are in common use to-day. The fish-tail burner, however, is not as efficient as the batswing, unless used with extremely rich gas. The tips used on flat flame burners were made of iron, but owing to their high conductivity they lowered the temperature of the burner and consequently were abandoned and replaced by lava or other forms of heat-resisting, non-conducting material.

In the earliest days of gas lighting the Argand burner, adapted for the use of gas, was standard. This burner was essentially the same as that used for oil, with the exception that no wick was supplied and that at the top there was a thin plate perforated with a large number of holes through which the gas issued, the different flames uniting to form one cylindrical flame. The Argand burner was for a long while the standard burner; but its drawbacks, due to first cost, difficulty in keeping the glassware clean, and the fact that it was extremely sensitive to draughts and had to be regulated as to the correct amount of air admitted, prevented its universal adoption. Although more efficient than the ordinary flat flame, it was superseded by this type in most places. In this connection it is interesting to note that as late as 1819, when Peckstone's "Gas Lighting" was published, meters had not been introduced, and that the method of charging was on the flat rate, which in London was £3 per year for an Argand burner burning from sunset to 9 o'clock at night; £4 per year from sunset to 10 o'clock, etc. This was, according to meter rates, about $3.75 per thousand; but the rate was actually less than this, owing to the fact that there was no guarantee that the customers turned the lights out at the hour agreed upon, and, furthermore, the adjustment of the burners was such that generally much more gas was used than should have been. The first meter was invented in 1815, but it was not for a good many years afterward that their use became universal. The standard meter as ordinarily used to-day was not invented until 1843.

In 1853 Sir Edwin Franklin invented the regenerative burner, which is essentially an Argand burner in which the products of combustion are used to heat both the gas and air supply to the burner. This preheating of the air and gas allowed a high temperature to be obtained, and, inasmuch as the light depends

upon the temperature of the carbon particles, a much higher efficiency was obtained by this method. Siemens, in 1879, improved on this, and his type of burner is still in use in certain places, although rapidly being replaced by the inverted mantle burner. It had numerous drawbacks, chief of which was the large size of the units. It was also costly to install, and, with the exception of use in lighting large spaces, was never widely introduced.

Up to the time of the introduction of the Welsbach mantle we find the following efficiencies of the different types of burners on coal gas of 16 candle-power:

Flat flame	from .6 to 2.5
Argand	from 2.75 to 3.2
Regenerative	from 7.0 to 10.0

The regenerative burner could be forced to considerably higher efficiency than this were it not for the inability of the parts composing the lamp to withstand the intense heat. It is to be noted that the Argand burner was the standard used for testing the candle-power of gas, and that gas was supposed to give 16 candle-power, with the proper Argand burner, for every five cubic feet of gas consumed. It is from this London standard that we get the standard 16 candle-power lamp as used in electric lighting.

MANTLE BURNERS.

The entire gas-lighting industry was revolutionized by the invention of mantle burners by Auer von Welsbach, in 1885. It is interesting to note, however, that many attempts along the same lines had been previously made before that time. In 1826 Gurney employed a cylinder of lime on which he played an oxy-hydrogen flame. This never proved a commercial success, although an attempt was made to use a modified form in Paris with oxy-coal gas. Gaillard, in 1848, made a mantle of platinum gauze, but, due to erosion caused by the gases, its life was short, and the plan was never commercially put into practice. The next step was that taken by Bunsen, in 1855, who produced the well-known non-luminous flame by mixing coal gas and air before ignition. Claymond, in 1882, devised a basket or cone of threads of calcium magnesia supported by a platinum

wire cage, and by means of a blow-pipe and Bunsen burner heated the same to high incandescence.

In 1885 Welsbach was working on the composition of rare earths as shown by the spectroscope. In order to make them more easy for examination than by placing them on the usual platinum wire, he immersed cotton in a solution of the metallic salts, which, after being burned, gave a replica of the thread, composed of the oxide of the metal, and glowed brightly in the flame. This led immediately to a study of the possibilities of using this process for lighting. Many different kinds of rare earths were tried, but it was finally determined that the most satisfactory combination was that of 99 per cent. of thorium and one per cent. of cerium, and this is the standard in use at the present time. It is interesting to note, in this connection, that if the percentage of cerium is either increased or decreased, the decrease in the candle-power is very marked. If, for example, the cerium be increased to five per cent., the candle-power is less than one-half of what it is at one per cent.; while if ten per cent. of cerium be used, the candle-power has fallen to about twenty per cent.

In a paper of this length it is needless to review the further history of the development of mantle burners, except to state that the inverted burner, as we now know it, was first introduced in the years 1900 to 1901, but was not perfected so that it came into popular use until several years afterward.

MODERN GAS LIGHTING.

Flat Flame Burners.

Flat flame burners are going rapidly out of use, except in special instances where the light is used more for a marker than for the amount of illumination given off, or where the burner is subject to such hard usage as to render the employment of a mantle burner inadvisable. It is to be noted that the rating of flat flame burner tips as ordinarily sold on the American market is of little value, as many instances are found where a tip rated as using one cubic foot of gas per hour gave as high a candle-power as a four-foot tip, with no greater amount of gas consumption.

The flame from an open gas burner appears to be prac-

tically transparent to light, as the horizontal distribution curve of such a flame is practically uniform. This is also true of the vertical illumination curve, with the exception of the slight shadow cast by the tip. In other words, the horizontal candle-power, as ordinarily measured, whether in a plane with that of the flame or at right angles to it, practically measures the mean spherical candle-power of such a unit.

Burners of this type are generally used with some form of globe to protect them from draughts. The effect of such glassware is usually to throw considerable light upward, so that where the light is wanted below the horizontal a burner of this type is inefficient as ordinarily employed.

The Argand burner is but seldom used to-day, except for testing the quality of gas, so that we need not here consider its characteristics.

Upright Mantle Burners.

Upright mantle burners have been greatly developed since their first introduction in 1886. In the early days there was a decidedly greenish tinge to the light, and even to-day, in most of the mantles, this greenish tinge is quite noticeable, especially in comparison with other sources of light. This has, however, been more or less rectified, and it is possible to-day to buy mantles on the market which have considerable variation in color. One of the drawbacks to the mantle burner has been that until recently only one size of mantle was available; namely, a mantle about 3½ inches high, giving a rated horizontal candle-power of from 60 to 80. At the present time, however, a smaller mantle is available, so that it is possible to get a wider variation. This has been one of the chief drawbacks of gas lighting as compared with electric lighting; namely, the lack of different sized lamps. Efforts to overcome these objections seem to be making progress in both upright and inverted burners, and it is likely that in the near future this advantage of electricity will be largely done away with.

An important point in gas lighting, especially with mantle burners, is the effect of pressure and also quality of gas on the light. Gas lighting would be much improved were burners selected with reference to this point, the same as electric lamps are selected for different electrical pressures in various districts.

The modern electric central station measures the voltage pressure at different parts of its circuits and buys its lamps accordingly, thereby furnishing proper lamps to the customer. In this way a great deal of complaint as regards poor service, etc., is done away with. If the gas companies followed the same plan they would undoubtedly have a much better satisfied class of customers, which is the best asset a gas company could have. Moreover, in this connection it is interesting to note that mantle burners are seldom or never bought on specifications. When the electric light company furnishes lamps to its customers it is only after the lamps have been bought on rigid specifications and have actually been tested to find out whether or not they comply with the requirements. In gas lighting, however, it is the usual policy of the gas company to furnish to its customers mantles and burners at all prices and grades, leaving the customer to select whatever in his opinion he sees fit to buy. The result is that the poorest and cheapest burners and mantles are most often found on the gas company's mains, resulting in the dissatisfaction of the customer and making him comparatively ready to change to electric lighting when opportunity offers. It would seem that if the gas companies are to retain their customers for lighting purposes it is necessary to take some steps along this line, as, with the introduction of the tungsten filament lamp, the mantle burner—especially under poor operating conditions—can no longer hope to compete as successfully as in the past.

With the upright mantle burner the distribution of light is considerably different from that of the open flame burner, which, as we have already seen, gives practically spherical distribution. The upright mantle burner gives its maximum light on the horizontal and comparatively little light directly underneath. Practically one-half the light is above the horizontal and one-half below. From the standpoint, therefore, of ordinary lighting, it is desirable to change its distribution. The ordinary shades as used with the mantle burner often accomplish their purpose of diffusion more or less successfully, but fail to redirect the light in directions below the horizontal. As a matter of fact, most upright burners, when equipped with diffusing glassware, throw two-thirds of their light above the horizontal, and, unless the walls and ceilings be extremely light, a large

amount of flux is lost. No distribution curves are given in this paper, as such are easily available elsewhere, in articles mentioned later. The thing to notice at this point is that the upright mantle burner is, generally speaking, not well adapted to utilize most of the light.

Inverted Mantle Burners.

Lamps should be rated in terms of their total flux rather than their mean horizontal candle-power, if we are to obtain comparative figures. From an illumination standpoint the important things about a lamp are the total quantity of light given out and the distribution of the same. The importance of this was not realized in the gas world until the introduction of the inverted burner. The standard inverted burner gives about 67 per cent. of its light below the horizontal and 33 per cent. above. This should be compared with the standard upright burner, which gives 55 per cent. above and 45 per cent. below. This means, for the same total flux of light, an increase of nearly 50 per cent. in the light below the horizontal, which, if this is taken as the useful light (as is often the case, but not by any means always), marks a great increase. Moreover, any glassware which is used with inverted burners is apt to increase rather than decrease the flux below the horizontal, especially if the glassware is of the open type; so that at the very start we have a marked increase in the net efficiency of the inverted as compared with the upright burner. In addition to this, the burner itself is slightly more efficient. Owing, furthermore, to the fact that the inverted burner lends itself more easily to artistic uses and is less likely to blacken the ceiling, as it can be placed lower, its introduction and use have been very rapid. With the introduction of this type many new kinds of glassware have been devised for it. Among these may be mentioned those of the prismatic type which are now available with the standard inverted mantle burner so as to give the three typical distribution curves—extensive, intensive, and focusing—which are found to fit the requirements of so many installations. The difficulty of breakage in connection with the use of pressed glassware has been largely obviated by the use of a metal collar. We can therefore safely state that with the improvements which

have already been made it is possible, with gas, to duplicate nearly all of the effects which can be obtained with electric lighting, both as regards ornamentation, distribution, ease of control, etc., and even surpass it in cheapness of operation.

Gas Arc Lighting.

The gas arc has been an attempt to obtain a large unit of high candle-power where a large flux of light is wanted. Owing to the size of the unit it has generally been thought to be highly efficient; but, due to causes which it is not necessary to enumerate here, it may be stated that the gas arc is no more efficient—if as much so—than the individual burner. We can therefore consider a gas arc to be nothing more or less than a large upright or inverted burner, and most of the remarks which have already been made as regards these two types can equally well be applied to the gas arc.

DIFFUSION.

One of the most important considerations in connection with mantle burner lighting is that of diffusion. When our only forms of burners were those of the Argand or open flame type, the necessity of diffusion was not great, as the candle-power per square inch was not in excess of five. With the introduction, however, of the mantle burner, with an intensity of many times this, and in addition a much larger quantity of light, it became necessary to shield the eye not only in order to protect it from harm, but also that the eye could be able to work with a wider pupillary aperture, and thus be able to see better. It is recognized now as one of the fundamental principles of good lighting that the light must be well diffused, and it is interesting to note that the passing of the bare mantle burner is becoming exceedingly rapid.

HIGH-PRESSURE GAS LIGHTING.

The ordinary pressures as used in gas lighting are from one-half of an inch at the burner up to, perhaps, two inches. Flat flame burners work best on comparatively low pressures, but with the mantle burners higher pressures are more suitable. It was soon found that an increase in light could be obtained by using higher pressures. For street lighting, there-

fore, it was logical that experiments should be made along these lines. The result has been the introduction of high-pressure gas burners principally for street lighting. With the ordinary low pressure in either the inverted or upright burner the candle-power per cubic foot is in the neighborhood of 20, whereas with high pressure this can be increased 2 to 2½ times. High pressure is adapted for either upright or inverted lighting; but, owing to the superior distribution obtained with the inverted type, this is rapidly supplanting the upright type. One of the most notable installations of this kind is in Berlin, where lamps rated at 4000 candle-power are employed, consisting of three mantles operating at a pressure of 50 to 60 inches of water and consuming about 25 cubic feet of gas per mantle, or 75 to 80 cubic feet per hour. It is interesting to note that the curve of distribution in the high-pressure burner is somewhat flatter than in the ordinary inverted low-pressure burner, a point particularly well adapted for street lighting.

Conditions being considerably different in this country from those abroad, it has not been adopted to any extent here, although it is likely to have a much wider use than at present. Owing to the extreme intensity of the mantle it would seem necessary to adopt some means for diffusion, and, although this is not as important in street lighting as in indoor work, it undoubtedly will soon become one of the first requirements.

HEAT CONSIDERATIONS.

The scope of this paper will not allow us to consider this question in detail, but it is sufficient to call attention to the fact that, while more heat is liberated from the production of light by gas than by electricity, it seems to be the consensus of opinion of those who have thoroughly studied the subject that such heat is useful in producing a ventilation which would be otherwise unattainable, and the products of combustion are carried off by this means, so that the quality of the air in a room is at least equal to that when other forms of lighting are used.

METHODS OF GAS IGNITION.

The ordinary method of lighting gas is by striking a match, but, owing to this inconvenience, many different schemes have

been adopted. The most common of these is the pilot light, consisting of a by-pass which allows a small quantity of gas to pass around the burner. This pilot light burns continually, and, whenever the main supply of gas is turned on, lights the mantle. The gas can be turned on either by turning the gas cock by hand or else by a pneumatic valve control. In this latter case a very small pipe is run to any convenient point, and at the end is attached a pneumatic plunger. When this is pushed in, air is forced through the pipe and turns the main valve in the gas supply pipe. In order to turn the light off, the plunger on the wall is pulled out, resulting in the valve in the gas supply pipe being thrown the other way. When properly installed the pneumatic control system is well adapted for this purpose, and does for the gas what the electric switch does for electricity.

Another method of ignition is that by the jump spark system, which has been in use for many years. By this system, when a button on the wall is pressed the gas is turned on and at the same time a spark ignites the same. The latest form of this is self-contained in the fixture.

Still another method of ignition is by a catalytic process. Advantage is taken of the well-known quality of platinum sponge to occlude gases. This is placed on the mantle, and when the gas is turned on the platinum sponge begins to glow and rises to a sufficient temperature to ignite the gas. Many efforts have been made to introduce this form commercially, but, up to the present time, not very successfully. Other chemical means have been introduced, such as an iron-ceria compound, but it is too early yet to state how successful this will be for this purpose.

GENERAL.

To one familiar with what has been accomplished in this field one of the most astonishing things in the gas situation is the lack of standardization. It is true that a good deal has been accomplished along this line within the last year or so, but there is still much to be desired. The writer would suggest some of the following steps to obtain improvements in gas lighting:

1. Greater range in the size of the units to better meet the

requirements of all classes of light, both in upright and inverted burners.

2. More reliable methods of commercially rating gas lamps so that when specifications are drawn up by the illuminating engineer or the architect giving certain definite illumination requirements, he can be reasonably sure of obtaining exactly what he wishes.

3. The lamp should be standardized similarly to the present methods of standardization of electric incandescent lamps.

4. Holders or fitters should be changed to conform to electric practice. Thus the gas fitter is 3⅜ inches in diameter; whereas the standard electric is 3¼ inches. Two-and-a-quarter-inch holders are common to both gas and electric.

In a paper of this length it is impossible to more than very briefly sketch the historical and present state of the art. Lately much has been published on this subject, and the writer would refer to the excellent papers on gas lighting appearing in the Johns Hopkins Lecture Course of the Illuminating Engineering Society, volumes 1 and 2. For different forms of photometric curves, for both upright and inverted burners, reference is made to "Practical Illumination," by Cravath and Lansingh. A complete bibliography of the subject is to be found in the lectures on gas lighting in the Johns Hopkins Lecture Course referred to above.

Pulverization of Metals by the Alternating Oscillating Discharge. ANON. (*Rev. Sci.*, xv, 1466.)—The metallic electrodes used to produce the oscillating discharge of a condenser are pulverized. A powderable quantity of metal is pulverized; thus, 1,000 discharges occurring between two gold spheres of 1 cm. diameter at a distance of 1.6 cm. pulverized 6 mg. The principal laws of this phenomenon were established by Kowalski and Banasinsky. For each metal the quantities pulverized at each discharge are very constant, and only differ by 1 or 2 per cent. at the maximum. But these quantities vary for each metal. For some metals for which this phenomenon has been observed the order of the magnitude of the pulverization is gold, platinum, zinc, iron, copper, silver, and aluminum. The pulverization increases with the explosive distance. Under equal conditions the weight of gold pulverized at 0.6 cm. was 1.9 mg., and at 1.6 cm. it was 6 mg. The pulverization diminishes as the capacity of the condenser diminishes, and this diminution is greater for large explosive distances than for smaller ones.

Electric Smelting of Zinc-Lead Ores at Sarpsborg, Norway, and at Trollhattan, Sweden. J. C. MOULDEN, and F. W. HARBORD. (*Chem. Eng.*, xiv, 510.)—The ores to be treated are complex sulphides, Broken Hill slime, and mixed sulphides of lead, zinc, copper, and iron, which have hitherto but little commercial value. The furnace has carbon electrodes, one in the bed and the other removable through the roof, and the smelting is affected by resistance with low voltage currents. The capacity of the furnace is 3 tons; its rate 2.8 tons of roasted ore per 23 hours at a horse-power of 350. The charge consists of roasted ore, coke or anthracite dust and flux, and the yield is crude spelter, zinc-lead powder, afterwards recharged, silver-bearing lead, a copper iron matter containing zinc and silver, and slag containing a little lead. Tests were run for a period of 27½ days at Trollhattan, in which were smelted 518 tons of Broken Hill slime, 19 tons of calamine, 22½ tons of zinc-lead powder, and the products were 161 tons of crude zinc, 2½ tons of lead, 36 tons of powder, and 17 tons of lead, which had leaked through the porous material of the furnace, and 9 tons of zinc-silver-lead skimmings. This means 64 per cent. of the zinc, 74 per cent. of the lead, and 46 per cent. of the silver. It is believed the yield can be made to reach 75 per cent. of the zinc, 80 per cent. of the lead, and 80 per cent. of the silver; and on this basis the profit would be about $7.50 per ton of slime, with slime at $14.15 per ton at Broken Hill, freight $11.25, cost of treatment $7.60, and electric heat at Trollhattan costing $7.50 per horse-power year, and the cost of calcination at Tyse at $3.50 per horse-power year.

Nickeled Gas Reflectors. R. W. WOOD. (*Astrophys. Journ.*, xxxiv, 404.)—It is well known that silver surfaces absorb a large proportion of the ultra-violet radiation which may fall on them, and this fact is of importance in any researches depending on the detection of short wave-lengths in various light sources. Recent experiments suggested the suitability of nickel for this purpose, and this paper gives directions how to ensure an even deposit of nickel on the surface of a glass mirror. The best results were obtained by electrical deposition from the double sulphate of nickel and ammonia. To illustrate the action of the nickel a set of photographs are given, showing the relative amount of ultra-violet radiation reflected by mirrors of various metallic films.

The Permeability of the Envelopes of Balloons by Hydrogen Gas. M. JULHE. (*Mon. Sci.*, lxxvi, 844, 285.)—Hydrogen is dissolved in the caoutchouc of the envelopes, which allows it to escape to the outside, as ammonia escapes from an ammoniacal solution. To avoid this inconvenience, the rubberized material should be lined on the inside of the balloon with an envelope impregnated with a solution of gelatine in glycerine.

FUNDAMENTAL CHEMICAL CONSTANTS.[1]

BY

PROF. EDWARD WILLIAMS MORLEY.

A MAN indulges in scientific research because it is fascinating. It gives more pleasure than golf; and, to have added to it so delightful a recognition as that given to me to-night, both in the medal and certificate, and also in the words introducing me, adds much even to the delight of successful research.

It was suggested that my topic should discuss the fundamental constants of chemistry. The importance of physical constants is, largely, that one of them holds condensed in small volume the essence of many observations, perhaps of all the observations which have ever been made in a given line. We have followed the motions of the planets with accurate observation for two hundred and fifty years. The number of observations is very great; the labor of consulting them would be enormous. But all their value has been extracted and condensed in a system of constants, seven for each planet. All planetary positions are wrapped up in these constants; from them, positions for the future can be unfolded as desired, with an accuracy corresponding to the accuracy with which the constants are known at a given time. A constant is compressed knowledge; it is like a seed, ready to grow and bud and blossom and fruit. The constants of chemistry are not so intricate as those of astronomy, and the labor of establishing them, although considerable in some cases, has not been so great as in the case of astronomy.

Chemical constants vary in nature and importance, and vary in their interest for the man who is not a chemist. Some are like words in a dictionary or figures in a mathematical table. It is needful that such constants be determined and tabulated, in order that a call for any one of them may be answered without delay and waste of time. For instance, a scientific man at present is endeavoring to find whether the properties of a compound are

[1] Presented at the Stated Meeting of the Institute, Wednesday evening, May 15, 1912, when Prof. Morley received the Institute's Elliott Cresson Medal.

functions of the changes of energy taking place in its formation from its elements. To examine this matter, he will need to know the melting point and the boiling point and the critical temperature of some well-known elements and of their best-known compounds. Then he will doubtless need to know the density of each, in the solid form, and the liquid and the gaseous; and then greatly to enlarge this list of measurable and well-determined properties. If most of these constants are already determined, he may be able to enrich our conceptions of the nature of the material universe within some short time; if they are not ready for him, he cannot find what he desires, and the world will be the poorer.

Some chemical constants are tools with which to increase human comfort, or human wealth, or the effective power of human effort. The knowledge of some thermal constants of certain steels enables us to add immensely to the strength and durability of steel constructions under strain,—to double or quadruple the strength of a crank shaft.

Other chemical constants are poems, or prophecies, or histories. It is of such constants that I wish to speak. They show us something about the nature of matter, which is the most interesting thing in the world, except human nature with its varied expressions. Excepting the study of human nature, the study of the nature of matter is the most fascinating subject open to us.

The fundamental constants of chemistry are the atomic weights. These were first investigated in order to fill up the pages of our dictionary. They were further studied in order to increase the effective power of human effort, as tools in analytical processes. But, while these constants were obtained for these prosaic ends, we find, to our great delight, that they perform the added service of assisting somewhat our insight, limited as it is, into the nature of matter.

About a century ago, Prout announced the theory that all atomic weights are integral multiples of the atomic weight of hydrogen. For example, the atomic weight of lithium is nearly equal to seven. Prout asserted that, when it is determined with final accuracy, the number will be *exactly* seven, and not nearly seven. So the atomic weight of carbon is about twelve, and that of oxygen about sixteen. Prout asserted that these numbers, when exactly determined, will be the exact whole numbers, twelve and sixteen.

The suggestion was a valuable one. It stimulated some of the best work which has been bestowed on atomic weights, and was well worth the great labor which it has stimulated. It was a long time before results were obtained sufficient to settle decisively the matter. One early result caused a modification of the theory. The atomic weight of chlorine was found to be not a whole number, but a number nearly equal to 35.5. The result of many most rigorous and exhaustive experiments gives the value 35.45, when oxygen is taken 16.00; accordingly, Prout's hypothesis was modified to assert that, when finally determined, it will be found to be exactly 35.50, an integral multiple of *half* the atomic weight of hydrogen. Subsequent modifications of the original theory assume the fourth or even the eighth part of the atomic weight of hydrogen as the basis.

If the theory were known to be true, it would allow an immense saving of labor. For instance, in determining the atomic weight of oxygen, if we were authoritatively informed that it must be either 15.50 or 16.00 or 16.50, we need only to make experiments rigorous enough and numerous enough to show that it is more than 15.5 and less than 16.5. Instead of the difficult process of *measuring*, we merely have to use the simple process of *counting*. Measuring must always be attended with errors, which cannot be eliminated except in part, and the avoiding of errors and the reducing of errors till they are negligible is a long and difficult process. But counting is affected, not with errors, but with blunders, and blunders can be avoided. In case of objects like atoms, which we cannot see, counting has to be effected by weighing; but a hundred sovereigns can be counted by weight without seeing the individual sovereigns, and can be counted with absolute precision by weighing with an accuracy of one-fourth of one per cent. But to pay out the same value of uncoined gold, we must weigh to the hundredth part of one per cent. So, if Prout's hypothesis were known to be true, an accuracy of one or two per cent. would show that the truth was 15.50 or 16.00; while, if the hypothesis cannot be assumed for our guidance, an accuracy of one-hundredth of one per cent. is barely sufficient. So, if the theory were proved to be true, it would permit an immense saving of labor from the time it was adopted as a guide, but there is a more interesting result from the truth of the hypothesis. It suggests a theory of the structure of matter. It

suggests that the atoms of many elements, perhaps of all, consist of the same identical matter put up in packages of different weight.* Hydrogen consists, according to one form of this theory, of two ultimate particles so adhering to each other that they are never separated in any chemical process known to us. Carbon consists, according to the theory, of twenty-four such ultimate particles, so held that chemical forces cannot separate them. So with oxygen, consisting of thirty-two; so with chlorine, consisting of seventy-one.

There has been much difficulty in determining atomic weights with a degree of accuracy sufficient to pronounce upon Prout's hypothesis. Even when they are determined as accurately as is now possible, some difficulty remains, at least in some minds, for many of the well-determined atomic weights were found to be curiously near to whole numbers. Perhaps the most serious difficulty, for a long time, was that we did not know the atomic weight of oxygen with sufficient accuracy. It so happens that most atomic weights are determined, as a matter of fact, by experimental comparison with oxygen, sometimes directly and sometimes indirectly. The atomic weight of carbon is determined by direct comparison with oxygen. Experiment shows that twice sixteen parts by weight of oxygen combine with twelve parts by weight of carbon. If, for the present, we assume sixteen as the atomic weight of oxygen, twelve is obviously the atomic weight of carbon, determined by direct comparison with oxygen. The atomic weight of potassium is determined by an indirect comparison. Five times sixteen parts by weight of oxygen combine with twice 35.45 parts by weight of chlorine, and 35.45 parts by weight of chlorine combine with 39.15 parts by weight of potassium, so that 39.15, by this indirect comparison, is the atomic weight of potassium.

Since oxygen is thus used as an intermediate term of comparison in most cases, we see that, in order to determine whether a given atomic weight is a multiple of the atomic weight of hydrogen, or of half of the same unit, we need to know with accuracy the atomic weight of oxygen referred to the same unit. To determine it has been difficult. Dumas, in a piece of work which will long be regarded as a classic of science, about the year 1842, made a series of determinations by the best method known at the time. As he was finishing the work, there was detected in his

laboratory a source of error attending all his experiments. He expressed the hope that his results were within the two-hundredth part of the truth, and his judgment was wonderfully accurate, for his final result was just the two-hundredth part too large. This result could by no means determine whether the atomic weight of oxygen is the whole number sixteen or is a tenth of a unit more or a tenth of a unit less. This same range of uncertainty becomes more troublesome in the case of larger atomic weights; it amounts to a quarter of a unit in the case of potassium.

To determine whether Prout's hypothesis or some of its modifications is true, it became necessary to determine the atomic weight of oxygen with far greater precision than attained by Dumas. It was found impossible to utilize the method of Dumas; although several of its sources of error can be removed, the annoying retention of water by the copper reduced from its oxide in the experiment could not be avoided in a workable apparatus. Using methods devised for the purpose, hydrogen was prepared containing less than 1/200,000 part of impurity. That is a simple matter to mention, but it took many months to accomplish! The proving that the impurity was as stated took six months, and required more invention than a little. Next, oxygen was prepared, of corresponding purity. That was really easy. These two were then separately weighed, were combined to produce water, and the water was weighed. The weight of oxygen used divided by that of the hydrogen used gave the atomic weight of oxygen. The weight of water produced divided by that of the hydrogen gave a second value of the atomic weight of oxygen. The fact that these two determinations agreed showed that there was no source of important error in the experiment.

To confirm the result obtained, the density of hydrogen was compared with the density of oxygen, and the ratio of the volumes in which they combine was determined. Multiplying these two ratios together, we secure a new determination of the desired atomic weight. For determining the density of hydrogen, no method heretofore used was found to be sufficiently accurate. A process was invented, in which hydrogen was absorbed in palladium and sealed up in a glass vessel. Globes holding forty litres were exhausted and sealed up by fusion. Then the hydrogen, sealed up by fusion in one vessel, was introduced into the sealed globes, without opening them to the air, after which vessel and

globes were left sealed by fusion. Weighing the vessel before and after, we learned the weight of the hydrogen used in the experiment; measuring the temperature and pressure of the hydrogen in the globes, we had accomplished the determination of the density of hydrogen without the use of stop-cocks, which leak, and without introducing any impurity into the hydrogen derived from apparatus through which it is passed. The density of oxygen was easily determined by usual processes, carried out with many precautions to ensure precision. Now, if it were true that two volumes of hydrogen combine with one volume of oxygen, the ratio of the densities would be the ratio of the atomic weights. But it is not precisely true that two volumes combine with one; we had, therefore, to determine what the accurate ratio is, and then correct the ratio of the densities. Since the value thus determined agrees with the two previously found, and since all three agree much nearer than to one part in ten thousand, we are entitled to feel much confidence in the mean result. This value is 15.879.

I am moved to mention a little matter which shows how a scientific man tries to keep himself free from unconscious bias. The determination first mentioned consisted of twelve experiments, in three or four series. In order not to be biased, the results were not computed from the weights observed, until the experiments were all completed. When you test the accuracy of the sights of a rifle, it is well to fire the string of shots without inspecting the target; then it is made sure that one does not unconsciously draw a bead differently on learning of the ill success of the previous shot. So, also, the agreement between the result of the synthetical experiments and those on densities was not known to me till the manuscript had been accepted for publication by the Smithsonian Institution; after that time, I went to Washington and completed the computations and first knew how well the two results agreed. The scientific conscience is rather rigorous.

This fundamental chemical constant is, I think, somewhat more than a figure in a mathematical table, or than a tool to facilitate analyses. It tells us something about a long-discussed question, and asserts a proposition concerning the nature of matter. The atomic weight of oxygen is not exactly sixteen, not 15.50, nor 15.75. Prout's hypothesis finds no support in

the most carefully determined atomic weight of oxygen, the only weight which up to that time had been determined by direct comparison with hydrogen, and a determination in which no source of important error has been suggested.

Further, now that we know the atomic weight of oxygen, we are ready to compare other atomic weights with that of hydrogen. If the atomic weight of oxygen is 15.88, then the atomic weight of carbon becomes 11.93, and that is not a whole number, nor a number ending in the fraction one-half, nor one-quarter, nor three-quarters. The atomic weight of chlorine, now that we know the atomic weight of oxygen, becomes 35.18, and that of potassium becomes 38.82; neither of these numbers is in accord with Prout's hypothesis. There are two other well-determined small atomic weights which equally fail to support the hypothesis in question. The onus of proof lies with small atomic weights. If we imagine, for the sake of argument, that the atomic weights best determined are liable to an error of one part in a thousand it is obvious that a small atomic weight, like that of carbon, is liable to an error of not more than a hundredth of a unit, which still leaves its evidential value uninjured. But an atomic weight like that of lead, which is over two hundred, is liable to an error of two-tenths of a unit, from which no conclusion could be drawn as to Prout's hypothesis. The small atomic weights which are well determined utterly fail to support Prout's hypothesis. So far as chemical methods now known can throw light on the matter, Prout's hypothesis cannot be true.

I presume that it will still have its adherents. One cannot but wish that the theory had been true, even when he admits that no modification of it which is consistent with sound physical principles has any support in the facts. Ingenuity can still modify the theory, and can make a modified theory which could not be disproved by experiment. We might assert that all atomic weights are integral multiples of one-hundredth or one-thousandth the atomic weight of hydrogen. That is like striking a ship to escape capture; the ship is no longer of service. A child, learning that ten dimes make a dollar, and knowing that a bank sometimes pays out five dollars in the form of a rouleau containing fifty dimes, might form the whimsical theory that all our silver coins consist of the proper numbers of dimes compressed till they adhere. He may imagine that a half dollar consists of

five dimes, hammered together, and a dollar of ten, which retain their identity and could conceivably be separated, though perhaps somewhat flattened and defaced. If, now, the child learns that a dollar weighs more than ten dimes and a half, he may, if the theory has become attractive to him, form a modified theory, according to which the dime is made up of two half dimes, compressed and adherent, and the dollar of twenty-one half dimes. If he next learns, by more accurate weighing, that the dollar weighs as much as 10.82 dimes, he may say that the number really is 10¾, and that the dollar is made up of forty-three quarter dimes. He might equally well say that it is composed of fifty-four fifths of dimes, or of sixty-five sixths of dimes; there is no end of possible suggestions, if he must maintain his early belief without evidence or in the face of evidence.

But civilization and science tend to put away childish things. The humble efforts which you have this evening rewarded with the Elliott Cresson Medal have been efforts to obtain evidence on a most attractive but illusory theory. It is delightful to know that the work of J. J. Thomson and others in a new field affords a more promising basis for speculations on the nature of matter, and so takes away our regret that the theory of Prout has given only negative assistance in that inquiry.

Density of Aluminum. ANON. (*Amer. Mach.*, xxxvi, 10, 388.)—Owing to the high purity of commercial aluminum of the present day, as compared with that on the market several years ago, at which time the density and coefficient of linear expansion of the metal were determined, these data were re-determined by Dr. F. J. Brislee, who reported his results at the sixty-first general meeting of the Faraday Society. The metal used contained aluminum 99.5 per cent. and about 0.25 per cent. each of silicon and iron. The density of cast metal was 2.708, that of hard-drawn rod was 2.705. Remelted aluminum had a density of 2.68, perhaps due to absorbed nitrogen. The coefficient of linear expansion of hard-drawn aluminum is:

$$Lt = L\ (1 - 0.00002432\ t),$$

and for annealed aluminum it is—

$$Lt = L\ (1 - 0.00002454\ t).$$

The figures given above for density are much higher than that usually ascribed, 2.583, as is also Dr. Seligman's 2.727 for the density of rolled aluminum sheets.

RECENT DEVELOPMENTS IN THE ELECTRICAL ART.[1]

BY

PROF. ELIHU THOMSON.

I APPRECIATE very highly the honor done me in the award of the Elliott Cresson Medal, and return my sincere thanks for the recognition accorded me. It may not be known to all present that my work in the electrical field virtually began within these walls and in this Hall. As a very youthful member of the Institute it was my privilege to take an active part in its work, beginning nearly forty years ago. At its exhibition in 1874, in the old freight depot at Thirteenth and Market Streets, the site of the present Wanamaker store, I was chosen one of the judges of awards in the class of optical, electrical, and scientific instruments. Appointed to deliver a course of five lectures on electricity early in 1877, in this very hall, I am happy to recall that the members were good to the youthful and untried lecturer, and filled the hall each evening. Serving with Prof. E. J. Houston and others on its Committee on Dynamo Electric Machines in the winter of 1877 and 1878, we were able to secure, for the first time, scientific data, voltage, resistance, current, illumination, efficiency, etc., on several dynamos for arc lighting and the single arc light which they each furnished.

The report of the committee appeared in the JOURNAL in 1878. When I left Philadelphia to go to New England in 1880 I had served on the Board of Managers of the Institute for some years.

It is then with a peculiar sense of gratitude and satisfaction that I receive this recognition of my work.

I have been asked to address you on this occasion on " Recent Developments in the Electrical Art." The applications of electricity now cover such a wide field that even to give a fair list of them would be a tax on your patience. Moreover, the term " recent " admits of great latitude, as the whole art is indeed recent. I shall use the word in a somewhat more restricted sense.

[1] Presented at the Stated Meeting of the Institute, Wednesday evening, May 15, 1912, when Prof. Thomson received the Institute's Elliott Cresson Medal.

But before referring to any recent advances I hope I may be pardoned for recalling, on this occasion, a few incidents besides those to which I have already alluded. My prime object in the course of five lectures given by me in this Hall thirty-five years ago was to show that electricity from any source was in essence the same, and so help to break down the barriers then existing in many minds between static electricity, dynamic, voltaic, thermo, and magneto electricities. Not to enter into details, I may state that at one of the lectures, in preparing my apparatus in this Hall to show that static or high-tension electricity could be converted into dynamic or low-tension currents, the result of the experiment first suggested the possibility and method of my latter invention of electric welding.

In the fall of 1878 I built a special dynamo, and a laborious piece of work it was for a foot lathe. It was used in conjunction with Professor Houston in lectures and demonstrations before the Institute. In fact, the machine was first tested and operated in this Hall. It was in some respects a unique machine, being either a self-exciting, alternating-current dynamo or a direct-current machine at will. As an alternator its winding made it two-phase, or biphase. Its voltage, by coupling its windings, could be varied in the ratio of one, two, and four. Its field could be similarly varied, so as to increase the range of variation, and it required three- or four-horsepower to drive it. In this Hall, and along with this machine, transformation with induction coils was experimented with. Such coils are now called transformers. This was in January and February, 1879. It may be interesting to note that, probably for the first time in the art, two transformers were used with their finer wire primaries connected in parallel to the dynamo line, while the coarse wire secondaries at lowered voltage supplied the work current. This is the arrangement now so extensively used in practice.

It was here, also, and at about the same time, I received my first heavy electric shock from an induction coil stepping up the current of the dynamo to about 10,000 volts. The convulsion threw me back and drew the wires from my hands. The accident certainly taught caution.

The working of this early dynamo, which machine, with other apparatus, is now preserved in our collection of early models at Lynn, Mass., was indeed the means of forming business affilia-

tions which later led to developing the Thomson-Houston arc lighting system, on which the large business of the Thomson-Houston Company at Lynn, Mass., was later built. This company having extended its business into railways, motors, incandescent lighting, etc., it was consolidated together with the Edison General Company, into the General Electric Company, in 1891.

In the early years of the art there was so much unknown that highly important discoveries and inventions followed each other at close intervals. Nowadays, this is not to be expected. The technical progress of to-day consists largely in the refining of methods, increasing efficiencies, improving construction, reducing costs, and extending the range of uses into new fields, while providing for the rapid growth of the industry in lighting, power transmission in all its varied phases, railways, electric heating and furnaces, electro-chemistry, and metallurgy.

Still, these later years are not without their technical triumphs in discovery and invention. The Edison carbon filament lamp, the influence of which on the growth of industrial electricity has been stupendous, was not known till the close of 1879. Improved in minor details, it remained for upwards of a quarter of a century without a rival for small units of light; the improvement coming by the substitution of tantalum and then of pure tungsten for the carbon; the gain in efficiency with the latter was such that approximately one-third of the energy would give as much light, and of a whiter and better quality. Tungsten had long been known in an impure state and in its compounds, and it was used as a component of special steels. Pure tungsten, as at first produced, was found to be a hard, glossy, brittle metal, absolutely without ductility or malleability in the cold, yet by careful research and persistent effort methods were found which at last yielded wire which could be drawn cold.

This was done in the research laboratory at Schenectady, and drawn tungsten wire filaments are now the standard. The unyielding brittle metal has been made so tractable that a single length of over three miles of wire, of a diameter less than that of a human hair, has been drawn. Tungsten drawn wire has the extraordinary strength of 600,000 pounds to the square inch of section. Ductile tungsten is now found to be superior to platinum for electric contacts, and far less expensive. It is also

the ideal material for the targets of Roentgen-ray tubes, not yielding where platinum would be melted rapidly in forcing the tube for the purpose of shortening the time of exposure in radiography.

Has the tungsten lamp reached the limit of its development? Certainly not. The knowledge gained in the past year or two renders probable a further advance in efficiency of lamps; leading to the confident expectation that more than 50 lamps of twenty candle-power each may be obtained from an expenditure of only one kilowatt of energy, or about 40 such lamps to the horsepower. These results may possibly be much exceeded, for the research laboratory is not yet through its work.

In recent years, as with incandescent lighting, electric arc lighting has been completely revolutionized. For a long time the arc between carbon electrodes was relied upon solely. It was at first open to the air—the so-called "open arc." Later the enclosed arc or carbon arc with a restricted supply of air served to minimize the consumption of the electrodes, but at a sacrifice of efficiency of light production.

Recently, we have seen the introduction of the various forms of flame arcs, luminous arcs, and the mercury arc lamp with its greenish light. By loading the electrodes of an arc with mineral or metallic compounds the main source of light is the flame between the electrodes, and not, as in the carbon arcs, the hot ends of the carbons themselves.

Many of the streets and open spaces in our large cities are now lighted by magnetite arcs, so named because the electrode which furnishes material to the arc is composed principally of magnetic oxide of iron, mixed with other substances destined to improve the color, steadiness, or efficiency. Development in this field is still going on actively. The characteristic arc light dynamos of former years are now seldom built. Mercury rectifiers instead convert into direct current the alternating currents from constant-current transformers, which in turn receive energy from the general supply mains extending from the great electric stations, which mains supply energy for incandescent lights or motors, and for other uses.

The tendency is now to generate in the station but one type of current, and supply all needs therefrom. A three-phase, alternating-current supply, working through rectifiers, trans-

formers, converters of various types, gives electrical energy in any form and at any voltage required. Thus the Fisk Street Station in Chicago has a capacity of 160,000 horsepower, and in it the three-phase, steam turbine dynamo units range up to 27,000 horsepower each, all varieties and conditions of load partaking of this enormous output.

While, in the early days of electric stations, lighting was the only load, it was foreseen that the distribution of power would eventually become of great importance. In recent years the application of electric motors has made enormous strides. They are fast becoming a universal adjunct to moving machines, replacing all small stationary steam engines and gas engines. Electric motors have already become a component part of machine tools and of many other machines formerly driven by belts from line shafting.

Perhaps, however, no better example of recent progress can be found than a modern high-tension transmission system, for it may combine within itself all of those features which have made electricity such an important factor of our later civilization. In such a transmission system there may be several generating stations far apart tied into the lines or net-work for conveying the electrical energy. In these stations water-power may be used to drive the dynamos, or steam, or both, or even internal-combustion engines may exist.

As generated, the electrical energy is too low in voltage for long-distance transmission. It may be, say, at only 2,000 volts while the transmission requires 100,000. In fact, a plant has recently been put into operation in which the line voltage is as high as 140,000. To obtain this increase of pressure the station current is "stepped up" by giant induction coils or transformers receiving the 2,000-volt current in their primary coils and delivering to the line 100,000 volts from their secondary winding.

Accurate instruments measure the output in amperes, volts, watts, and other factors. In the large stations the manipulation is often by a system of "remote control" whereby, by means of electric relay apparatus, outputs of many thousands of horsepower are controlled by a single person operating push-buttons or small master switches. Here, also, signals and instruments exist for showing him the operating conditions of the plant

at any time. Telephones connect the various stations, and parts thereof, over hundreds of miles. Automatic lightning arresters, fuses and circuit-breakers are on guard in case of accident.

Sets of line wires of copper or aluminum, three wires in each set, lead off into the far distance from these great stations, and are supported on high-tension insulators, which are sustained on poles, or upon tall towers of latticed steel. These lines are very much alive. They are dangerous to approach; for the kind of electricity they carry is second cousin to the lightning, for it can jump spaces of many inches. If we follow such a line we may find that it leads to a substation near a town, or to a group of factories, or to a substation power-house operating a railway or a mine. Here it is "stepped down" by reversing the process which gave the energy its high pressure. Step-down transformers reduce its voltage to a more manageable amount; perhaps to again about 2,000 volts. These transformations have caused but small loss, for the efficiency of the large transformers is but little less than 100 per cent. We find again, in the step-down station, the measuring instruments, automatic apparatus, and appliances for control. And now lines lead off in various directions carrying the 2,000-volt current, some of which is finally again transformed down, perhaps, to 100 or 200 volts, for low-tension supply on the consumer's premises, where his electric meter registers the amount of energy used by his lights, his motors, and the like.

Part of the energy may, through rectifiers, supply the current for the arc lights on the streets or in the stores. Vacuum-tube lights even may be operated. Electricity has given us sufficient variety in our means for producing light. Another part of the energy may be changed, by machines called rotary converters, and adapted to the operation of railway car motors, which need a direct current of about 600 volts.

Still another fraction may work apparatus employed in changing large storage batteries, or may be further divided and rectified for the batteries of automobiles. Energy may be taken from the system for electric stoves or cooking apparatus or for warming. It may be also consumed in heating metal, as in electric welding, or in electric purposes. It may produce ice in refrigerating machines driven by electric motors. The applications of electric motors are already innumerable. The time will come when cool-

ing in summer will not depend on ice delivered at our doorsteps or in our refrigerators. We may turn a switch, setting in motion a small refrigerating apparatus which transfers heat from water to be cooled or frozen to other water to be warmed. A modicum of the electric output may go to the uses of the physician in such indispensables as Roentgen-ray tubes. The dentist also calls for his supply.

In recent years electricity has added to our resources many remarkable and valuable products. Among those are carbide of calcium and from it acetylene gas. The electric furnace gives us such ideal grinding materials as carborundum and alundum. By way of contrast to these, it furnishes artificial graphite for lubrication. It furnishes supplies of such elements as silicon and boron, until recently practically unknown even in the laboratories.

Aluminum, magnesium, sodium, calcium are made commercial products by electrolytic methods of production. Through cheap aluminum we have thermite for welding. We also obtain by it pure metals, such as manganese for forming alloys. Lastly, in late years large electric furnaces enable us to secure high temperature for refining great baths of steel, or producing special high grades from crude material. Electrochemical baths refine our copper and yield such products as chlorine, caustic soda, and bleaching powder, as well as the chlorates. Special electric furnaces give us phosphorus for matches, and others, carbon bisulphide. Within a few years past water-power has been employed, as in Norway, in the commercial production of nitrates, by combining the nitrogen and the oxygen gases of the air in huge, specially-formed electric arcs. These nitrates add to our agricultural resources, on which the food supply and, as a consequence, the population of the world depend.

It would be out of place here to recount the numerous improvements which our electrical machines are constantly undergoing. There are many minor advances, improvements in design, in disposition and character of materials, in manufacturing methods, and the thousands of things that contribute to an art so varied and extensive in its field.

Very recently I came across by accident an article on the "Future of Electricity" which I had written for a magazine now defunct. It was published in 1892—just twenty years ago. The forecast therein given has not only in the main proven true,

but in not a few instances has been many times exceeded. Wireless telegraphy, then predicted as a possibility between ship and shore for moderate distances, in spite of storm and fog, has crossed the Atlantic. Telephony, alluded to as feasible over hundreds of miles, has thousands to its credit. Long-distance transmission of electric energy has very greatly exceeded our most sanguine anticipations of twenty years ago. Our dynamos are of far greater capacity than any of us could have imagined possible. In all directions our expectations have been far exceeded, and unexpected new discoveries have opened up a range of newer applications.

We must leave the future to tell its own story, lest we repeat the same underestimation.

Fusion of Pure Quartz. BILLON-DAGUERRE. (*Comptes Rendus*, cliv, 506.)—The powdered quartz in a carbon crucible is first heated by the electric arc till softened, at about 1800° C., then further heated by the oxy-hydrogen flame and drawn out into rods, from which tubes, crucibles, basins, and other articles are produced. Blocks of quartz for optical purposes are manufactured by casting and compression.

Copper Amalgam. A. GUNTZ and DE GREIFT. (*Comptes Rendus*, cliv, 357.)—Copper amalgam prepared in the cold (*e.g.*, by electrolysis with a mercury cathode), and submitted to increasing pressures in chamois leather, loses mercury until a residue of the composition HgCu is left, from which mercury cannot be removed even by a pressure of 6,250 kilos. per sq.cm. Amalgams of this composition prepared in the cold melt at 135° C., and, after cooling again, practically the whole of the mercury can be removed by pressure. Copper amalgams, shortly after being heated above 135° C., possess densities equal to those calculated on the assumption that the two metals are simply mixed; but if the amalgams are prepared in the cold, or if, after heating, they have remained cold for several days, their densities are considerably higher than those calculated. It is concluded that copper amalgams formed in the cold contain a compound, Hg Cu, dissolved in excess of mercury, which may be removed by pressure in chamois leather. This compound is decomposed at 135° C., and, on cooling again, requires about three days to be re-formed.

EFFICIENCY IN EDUCATION.[1]

BY

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We are living at a time in which the question of securing the highest efficiency in every form of business enterprise has become a dominant one. No man would undertake a business unless he could assure himself at the very outset that every department of it could be conducted both economically and efficiently.

For a man to take such precautions is not only an evidence of good common sense, but the stand is one that must be taken as a matter of self-protection.

There have been times in the progress of almost any kind of business when it was possible to keep it alive, and even prosperous, in spite of the careless and wasteful methods employed; but at the present time, when our excellent systems of communication have brought all parts of our country together and when manufactured products can be quickly delivered to the places where they are needed, however remote, any manufacturer is almost as keen a competitor of another a thousand miles away as though they both lived in the same city.

Space and time have been annihilated, from the business stand-point, and the man who does not meet the standards of economy and efficiency set up by his competitors will be crowded off the course by their inertia of motion or left stranded far in the rear by his own inertia of rest.

Since there is such a demand for high efficiency in the business world it may be well for us to inquire whether there can be efficiency in education, and, if so, how it may be secured.

At the very beginning we are met with fundamental differences in the conditions. In the factory one has to do with inert

[1] Address delivered at the meeting of the Alumni Association of The Franklin Institute, March 23, 1912.

matter; in the school with individuals whose actions are governed by their own wills. In the factory we deal with a piece of automatic machinery which does the thing for which it was made, or, if it does not and refuses to work at all, it is largely our own fault in allowing it to get out of repair and become useless. In the school we deal with separate personalities, no two of which are alike and no two of which are sure to do the same thing under exactly the same conditions; while, if the results obtained are not what we want, we are limited to the giving of advice, which is accepted or not according to the mood or fancy of the one who receives it.

It would seem, then, by this comparison of the material with which we have to deal, that the problem becomes a much more difficult one when we bring it into the field of education.

When a man designs a piece of automatic machinery he must, in order to be at all successful, have very definitely in mind the purpose for which the machine is being designed: what it is that the machine is to do. To take any other course would stamp the attempt with failure from the start.

To secure efficiency in education, should there not be the same clear-cut, definite knowledge of the result to be obtained? There is in both cases a groundwork of that which is fundamental. In the case of the designer it is his knowledge of the physical qualities of the materials to be used. He must know what the limit of elasticity is, of the material that he proposes to use in every part. He must know whether it will be able to stand the strains that will be put upon it in the work that it has to do. He must know whether there is a choice in this material, and he must make choice of the very best, or the next man who takes up the problem and who can profit by what he has done will so far surpass him in his design that the work shall be a failure through the very competition that it invited, by not being the best machine that could be made. Not only must the designer have this fundamental information, but this fundamental strength, this fundamental elasticity, this fundamental adaptability must have been put into the material by the maker, or the machine will be a failure through his lack of this fundamental knowledge.

The same thing obtains in efficient education. There are,

first of all, the fundamentals to be obtained and to be made such a part of the every-day life of a child that they seem to him things that have always been known.

At the very foundation of these fundamentals I would place the ability to think straight. Perhaps you think that I am beginning at the wrong end and that the ability to think straight is the aim and end of education and cannot be had at its beginning. Well, there may be some reasons for your opinion, but I really believe that in order to secure efficiency in education it must be founded upon the ability to think straight, to have the moral sense of what is right and what is wrong, and, moreover, I believe that this ability is common to most men and women.

To the man who does not think straight or who will not, an education brings at most the ability to succeed in things in which it would be better if he should fail. There is another phase of thinking straight, and that is to have one's thoughts clear and well defined. This, too, seems to me to be one of the fundamentals in education.

If we are to have any hope whatever of being of service to those about us, or of being influential among them, we must be able to present our opinions to them in a clear and forceful manner, and this we cannot do unless we are able to think them out clearly to ourselves. It is a pleasure to listen to a man who has a definite purpose in his mind and also has the ability to express that purpose in fitting words, and so I would include, as another fundamentally important thing, an ability to use one's native tongue forcefully.

Too frequently, none of the things that I have mentioned are considered as a necessary part of an education at all. In addition to the ability to understand and use the English language, there is one other department of knowledge that lies at the very foundation of daily life, and that is mathematics. Now, do not think of the kind of mathematics that delights the mathematician, for what I mean is the fundamentals—that is, the elementary mathematics, such as arithmetic, algebra, and geometry. If we consider for a moment that the great discoveries of Nature were most of them made with just these branches of mathematics applied to the questions in hand, pos-

sibly adding trigonometry for the use of the astronomer, we shall see that the essentials are elementary.

No one can live in our times, surrounded as we are by the most striking applications of science, without feeling that a study of the natural sciences is required in order to consider that we may be entitled to the name of educated people. Here, again, the fundamentals are of the greatest importance. Take, for example, electricity, which has so general an application in lighting, heating, and furnishing us a means of transportation. As a matter of fact, the essentials are few. It is in the applications that there is so great a divergence. Let a man be thoroughly grounded in the elementary principles of magnetism and electricity: it is a simple matter of diligent application of these principles that solves the most intricate problems to be met.

When we calculate the efficiency of an electric generator, for example, we find that it is the ratio of the power output to the power output plus the *losses*. How are these losses made up? Why, there is the loss in the shunt field, and this we expect and are willing to allow, because if there were no shunt field there would be no lines of magnetic force for the armature wires to cut and there would be no voltage generated for delivery at the brushes. Then there is the armature loss, and this we expect, for there must be wires to cut the lines of force, and they all have some resistance; hence there is a heat loss in the armature that increases as the current increases. Then there are the stray losses—those heart-breaking losses that the designer tries to cut down and generally fails: losses that have no compensation; that have no redeeming feature; that are only detrimental to the machine, and that cut down its efficiency ten per cent. How are these losses made up? Why, there is the friction between the shaft and bearings, between the brushes and commutator, between the rotating armature and the air. There is the time-lag or hysteresis loss, and there is the eddy current loss which is due to currents set up by the cutting of the magnetic lines by the armature core or the pole pieces, and which only serve to heat up the machine and increase its resistance. Now, how does this apply to education? What I would say is that if we wish to increase efficiency in education we must cut down the losses. Perhaps there are some of them

that are really so connected with the system or method that they cannot be avoided. But there are certain others—the stray losses—that are wholly harmful, and these should be eliminated. The friction losses between teacher and taught should disappear. The system should be so changed that friction between both teacher and taught and the system should not be possible. And, greatest of all, the eddy currents, those vampires that destroy uselessly, caused by inattention, lack of interest, lack of enthusiasm, should be themselves destroyed.

To insure efficiency in education there must be a greater saving in another great loss, and that is in the loss of time. This requires that one shall know without question what it is that he wants to inform himself on, and not flounder along helplessly for months or years with no definite goal in view. You who have had the opportunity of taking the courses that the Franklin Institute offers have had the advantage of knowing definitely what it was you wanted to study. You have had the opportunity placed before you of applying yourself directly to the problem in hand, and if you have taken advantage of these opportunities you have the consciousness that the education so secured has brought with it something that has been of real and lasting value. I believe we should never look upon our education as a thing of the past. I greatly admire the point of view of the centenarian who had completed his hundredth year in this year 1912 who went to a shoemaker to have a pair of shoes repaired and was very insistent that they should be made strong enough to last a long time. The shoemaker said to him, "Why, you are a hundred years old, and still you seem to be as anxious that these shoes shall last as though you were to live another hundred years." "Well," said the old man, "perhaps I shall. I am a great deal stronger than I was when I started out in 1812." That is the kind of optimism that I like.

Refractories. F. A. J. FITZGERALD. (*Med. and Chem. Eng.*, x, 129.)—*Alundum* (*fused alumina*).—Pyrometer tubes of alundum are now made; they are more refractory and have a higher heat conductivity than porcelain or fire-clay tubes. As a roof for electric steel furnaces alundum bricks resist the high temperature, but show a tendency to break off in layers, owing to the action of lime vapor arising from the basic slag.

Maganese Steel. ANON. (*Amer. Mach.*, xxxvi, 9, 348.)—An ingot of manganese steel is as brittle as glass, but when re-heated to a temperature of 1000° C. or higher, and suddenly chilled by plunging into water, it becomes as ductile as soft carbon steel or wrought iron, and has three times their tensile strength. Manganese steel cannot be forged except with great difficulty, and, as there is no method known of softening it, cannot be machined for practical purposes. Articles made of manganese steel are therefore cast, re-heated, and chilled.

The Atomic Weight of Calcium and Molecular Weight of Lime. OECHSNER DE CONINCK. (*Mon. Sci.*, ii, 843, 208.)—The molecular weight of lime was determined from calcium formiate, made from very pure lime and crystallizable formic acid. It was first gently calcined, then at a high temperature. In one experiment Iceland spar was dissolved in dilute hydrochloric acid, the solution treated with ammonia and precipitated by ammonium oxalate. Four determinations were made with formiate and the last with oxalate. The result gave the figure 56.02 for lime and 40.03 for calcium, which is closely approximate to the figure 40.07 adopted by the international commission on atomic weights.

Sodium Perborate as a Bleach. ANON. (*Revue Sci.*, xiii, 407.)—Sodium perborate, $NaBO_3$, under the name of Persil is now used for bleaching linen. A solution of sodium perborate heated to 60° C. gives sodium metaborate and oxygenated water. For bleaching cotton, it is first boiled with alkasil (sodium monosilicate), and then in a bath containing five per cent. of perborate. The temperature should be below 25° C. for bleaching flax, hemp, jute, and ramie: hypochlorites, sodium peroxide, and perborate are used concurrently. The last gives a very decided white color, after several hours' steeping at 70° to 80° C., and maceration. After the use of hypochlorites the perborates act as an antichlor. Oxygenated water is used to bleach straw, and is obtained by the use of sodium peroxide or perborate in a solution acidified with oxalic acid. A one per cent. solution of blankit (sodium hydrosulphite) is also used. Plants, used as ornaments, are sterilized and decolorized by a solution of perborate. Wool is bleached by perborate, preferably in water acidified with lactic acid. To bleach silk, it is first washed in soapy water mixed with benzine, which emulsifies the fatty matters, particularly sericine; then 2 to 3 kilograms of perborate are added to a bath of 1,000 litres, and 10 kilograms of cocoanut-oil soap. Chinese hair can be decolorized to white with baths of soap, to which alkasil and perborate are added, finishing by an immersion in ammoniacal oxygenated water.

NOTES FROM THE BUREAU OF STANDARDS.

THE MELTING POINTS OF FIRE BRICKS.[1]

BY

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WE are accustomed to thinking of a melting point as a temperature at which a substance changes from a rigid to a fluid condition, but a melting point can be precisely and rationally defined only as the temperature at which a crystalline or anisotropic phase and an amorphous or isotropic phase of the same composition can exist in contact in equilibrium. While this definition is satisfactory for pure substances, so complex a mixture as an ordinary fire brick usually has no single definite melting point according to this definition, since several anisotropic phases may be present, all differing in composition from the isotropic phase produced by fusion. We can then only select the temperature at which the transition from a rigid to a fluid state seems most distinct, and can call this the melting point only by apology. In the case of fire bricks, the transition temperatures so found are, fortunately, sufficiently distinct. I have taken as the melting point the lowest temperature at which a small piece of the brick could be distinctly seen to flow.

The experiments were conducted in an Arsem graphite resistance vacuum furnace. The samples were usually inclosed in a refractory tube made of a mixture of kaolin and alumina in the proportions to form sillimanite, to protect them from the small amount of reducing gas in the furnace, although the action of this gas was slight. The samples were observed through a glass window in the top of the furnace.

The temperatures were determined by means of a Morse opti-

[1] Abstract of forthcoming Technologic Paper to be issued shortly.

cal pyrometer of the Holborn-Kurlbaum type, which was sighted vertically downward through the glass window. The carbon-filament pyrometer lamp was calibrated by two methods. In the first calibration it was sighted into a platinum resistance furnace in which black-body conditions were obtained, and the temperature of which was measured by platinum platinum-rhodium thermocouples. These thermocouples had been calibrated against the freezing points of pure metals. In the second calibration the lamp was calibrated against the freezing points of metals directly, without the intermediation of thermocouples. The metals used were copper, silver, and the copper-silver eutectic, which freeze at 1083°, 961°, and 779°, respectively. The metals were melted in the vacuum furnace in graphite crucibles, the pyrometer being sighted into a thin-walled graphite tube inserted in the metal. The pyrometer readings corresponding to the freezing points were determined by means of cooling curves. With silver and copper, heating curves were also obtained.

As the melting points to be measured were above the working limit of the pyrometer lamp, an absorption glass was interposed between the pyrometer and the furnace.

The true temperatures were then found from the apparent temperatures measured through the glass, by means of the equation

$$\frac{1}{T_2} - \frac{1}{T_1} = A,$$

where T_1 is the absolute temperature of the furnace, T_2 is the apparent temperature observed through the glass, and A is a constant. The value of A was determined by calibrations at various temperatures. A small correction was also applied for the absorption and reflection of the glass window of the furnace.

The samples, which were from one to two centimetres in diameter, were heated at the rate of about ten degrees per minute when near the melting point. It was found that in the case of certain bricks made of heterogeneous material of relatively low melting point the melting points were slightly higher after six hours' heating to 1550°, apparently as the result of the gradual running together of dissimilar particles to form a mixture having a higher

melting point than the most fusible of the original materials.

The results are summarized in the following table:

Material.	Number of Samples.	Melting point, Centigrade.
Fire clay brick	41	1555° to 1725° mean 1649°
Bauxite brick	8	1565° to 1785°
Silica brick	3	1700° to 1705°
Chromite brick	1	2050°
Magnesia brick	1	2165°
Kaolin	3	1735° to 1740°
Bauxite	1	1820°
Bauxite clay	1	1795°
Chromite	1	2180°
Pure alumina		2010°
Pure silica		1750°

The value 1750° given for silica is not the true melting point, but represents approximately the temperature at which the silica flows distinctly. It was found that silicon carbide does not melt below 2700°; it becomes unstable at much lower temperatures.

MELTING POINTS OF CHEMICAL ELEMENTS.[1]

The values of the melting points used by the Bureau of Standards as standard temperatures for the calibration of thermometers and pyrometers are indicated in capitals. The other values have been assigned after a careful survey of all the available data.

As nearly as may be, all values, in particular the standard points, have been reduced to a common scale, the thermodynamic scale. For high temperatures, and for use with optical pyrometers, this scale is satisfied very exactly by taking $c_2 = 14500$ in the formula for Wien's law connecting I, monochromatic luminous intensity of wave length λ, and T, absolute temperature: $\log I/I_1 = c_2 \lambda \log e \ (1/T_1 - 1/T)$. For all purposes, except the most accurate investigations, the thermodynamic scale is identical with any of the gas scales.

[1] From Circular No. 35, June 15, 1912.

MELTING POINTS OF CHEMICAL ELEMENTS.

Element.	F.	C.
Helium	<-456	<-271
Hydrogen	-434	-259
Neon	-423	-253?
Fluorine	-369	-223
Oxygen	-360	-218
Nitrogen	-346	-210
Argon	-306	-188
Krypton	-272	-169
Xenon	-220	-140
Chlorine	-150.5	-101.5
MERCURY	-37.7	-38.7
Bromine	$+18.9$	-7.3
Cæsium	79	26
Gallium	86	30
Rubidium	100	38
Phosphorus	111.4	44
Potassium	144	62.3
Sodium	207.5	97.5
Iodine	236.5	113.5
Sulphur	S_I 235.0 S_{II} 246.6 S_{III} 224.2	112.8 119.2 106.8
Indium	311	155
Lithium	367	186
Selenium	422–428	217–220
TIN	449.4	231.9
Bismuth	520	271
Thallium	576	302
CADMIUM	609.6	320.9
LEAD	621.1	327.4
ZINC	786.9	419.4
Tellurium	846	452
ANTIMONY	1166	630.0
Cerium	1184	640
Magnesium	1204	651
ALUMINUM	1217.7	658.7
Calcium	1490	810
Lanthanum	1490	810?
Strontium	.....	$>Ca<Ba$?
Neodymium	1544	840?
Arsenic	1560	850?
Barium	1560	850
Praseodymium	1725	940?
Germanium	1756	958
SILVER	1761	960.5
Glucinum	.....	$>Ag$
Radium	.....	?
GOLD	1945.5	1063.0
COPPER	1981.5	1083.0
Manganese	2237	1225
Yttrium	.....	?
Samarium	2370–2550	1300–1400
Scandium	.....	?
Silicon	2588	1420
NICKEL	2646	1452
Cobalt	2714	1490
Chromium	2750	1510
IRON	2768	1520
PALLADIUM	2820	1549
Zirconium	3100	1700?
Thorium	>3090 $<$Pt.	>1700 $<$Pt.
Vanadium	3150	1730?
PLATINUM	3191	1755
Beryllium	>3270	>1800?
Ytterbium	.....	?
Titanium	3450	1900?
Rhodium	3525	1940
Ruthenium	>3550	>1950
Columbium (Niobium)	4000	2200?
Boron	4000–4500	2200–2500
Iridium	4170	2300?
Uranium	.....	?
Molybdenum	4500	2500?
Osmium	4900	2700?
Tantalum	5160	2850
TUNGSTEN	5430	3000
Carbon	>6500 for $p=1$ At.	>3600 for $p=1$ At.

THE RELATION OF THE HORSEPOWER TO THE KILOWATT.[1]

THERE was, before 1911, no precise definition of the horsepower that was generally accepted and authoritative, and different equivalents of this unit in watts are given by various books. The most frequently used equivalent in watts, both in the United States and England, has been the round number, 746 watts; and in 1911 the American Institute of Electrical Engineers adopted this as the exact value of the horsepower. It is obviously desirable that a unit of power should not vary from place to place, and the horsepower thus defined as a fixed number of watts does indeed represent the same rate of work at all places. Inasmuch as the "pound" weight, as a unit of force, varies in value as g the acceleration of gravity varies, the number of foot-pounds per second in a horsepower accordingly varies with the latitude and altitude. It is equal to 550 foot-pounds per second at 50° latitude and sea level, approximately the location of London, where the original experiments were made by James Watt to determine the magnitude of the horse-power.

The "continental horsepower," which is used on the continent of Europe, differs from the English and American horsepower by more than 1 per cent., its usual equivalent in watts being 736. This difference is historically due to the confusion existing in weights and measures about a hundred years ago. After the metric system had come into use in Europe, the various values of the horsepower in terms of local feet and pounds were reduced to metric units and were rounded off to 75 kilogram-metres per second, although the original English value was equivalent to 76.041 kilogram-metres per second. Since a unit of power should represent the same rate of work at all places, the "continental horsepower" is best defined as 736 watts; this is equivalent to 75 kilogram-metres per second at latitude 52° 30′, or Berlin. The circular gives tables showing the variation with latitude and altitude of the number of foot-pounds per

[1] Abstract, Circular of the Bureau of Standards, No. 34; June 1, 1912.

second and of kilogram-metres per second in the two different horsepowers.

These values, 746 and 736 watts, were adopted as early as 1873 by a committee of the British Association for the Advancement of Science. The value, 0.746 kilowatt, will be used in future publications of the Bureau of Standards as the exact equivalent of the English and American horsepower. It is recognized, however, that modern engineering practice is constantly tending away from the horsepower and toward the kilowatt. The Bureau of Standards and the Standards Committee of the American Institute of Electrical Engineers recommend the kilowatt for use generally instead of the horsepower as the unit of power.

Fallacies in the Theory of the Organic Origin of Petroleums. EUGENE COSTE. (*Mining Sci.*, lxiv, 493.)—Two simple patent geological facts are efficient to disprove and condemn all theories of the organic origin of petroleums: (1) The remains of the soft organic tissues of animals were never entombed in the sedimentary rocks, and (2) the vegetable organic remains were always transformed into coal. The production of CH_4 from decomposing vegetation occurs during the transformation of such material into peat, carbonaceous matter, and coal rather than into petroleum. Everywhere there is a lack of connection between coal beds and petroleum deposits. The analogy between the CH_4 of the coal and of the petroleum is only one of chemical composition, indicating simply that CH_4 can be formed in two or more different ways. The rapid and complete disappearance of all dead animal tissues is well known, while the formation of strata is such a slow process that even the hard parts of animal organisms are often much destroyed before their final entombment. The fossiliferous beds of all ages are entirely barren of petroleum. The abundant production of hydrocarbon gas in volcanic phenomena cannot be disputed. These phenomena manifested along great tectonic disturbances of the earth's crust lead to the belief that fissures caused by dynamic disturbances of the crust permit the escape of vapors and gases, which are trapped in porous portions of the sedimentary strata to form oil and gas deposits. Oil pools are always found grouped along fissured zones of disturbances, and never extend far from the fractures which formed the channels of hydrocarbon emanations from the interior. The same quality of oil may be found in all kinds of strata, as along the Appalachian belt. As much as 0.2 per cent. carbon has been shown to exist in massive crystalline rocks, which is twenty times as much carbon as may be found in the atmosphere; showing that the source of carbon is far from residing in the organic kingdom.

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LIBRARY NOTES.

Purchases.

FOERSTER, M.—Taschenbuch fur Bauingenieure. 1911.
BURGESS, G. K., and H. LE CHATELIER.—The Measurement of High Temperatures. 1912.
TIMBIE, W. H.—Elements of Electricity for Technical Students. 1911.
FULLER, G. W.—Sewage Disposal. 1912.
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Methods of Organic Analysis. By Henry C. Sherman, Ph.D., Professor of Food Chemistry in Columbia University. Second edition, rewritten and enlarged. 407 pages, illustrations, 8vo. New York: The Macmillan Co., 1912. Price, in cloth, $2.40 net.

Chemical Arithmetic and Calculation of Furnace Charges. By Regis Chauvenet, A.M., B.S., LL.D. 302 pages, 8vo. Philadelphia: J. B. Lippincott Company, 1912. Price, in cloth, $4 net.

Pennsylvania Topographic and Geologic Survey. Report No. 5. Preliminary Report on the talc and serpentine of Northampton county and the Portland cement materials of the Lehigh district. By Frederick B. Peck. 65 pages, plates, maps, 8vo. Harrisburg State Printer, 1911.

To Establish an Independent Health Service. Speech of Hon. John D. Works, of California, in the Senate of the United States, Monday and Tuesday, April 29 and 30, 1912. 78 pages, 8vo. Washington: Government Printing Office, 1912.

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Zur Priorität der Erdantennen von L. Zehnder und F. Kiebitz. Sonder-Abdruck aus den Verhandlungen der deutschen Physikalischen Gesellschaft. 1 page, 8vo. Braunschweig: F. Vieweg & Sohn, 1912.

BOOK NOTICE.

COLLEGE MATHEMATICS NOTEBOOK. By Robert E. Moritz, Ph.D., Professor of Mathematics in the University of Washington. 100 pages, 8 x 10½ inches. Published by Ginn & Co., New York. Price, $1.

This book consists of a "Biflex Binder" loose-leaf notebook with filler, including thirteen printed pages of formulas from algebra, geometry, trigonometry, calculus, etc., mechanics, thermodynamics and electricity and magnetism; four pages of mathematical tables; five pages of logarithmic-ruled paper, and five pages ruled for polar coördinates.

The formulas and tables are well selected and arranged, and the notebook should be of service in the lecture-room or laboratory.

CURRENT TOPICS

Lamp Characteristics. M. TAPPLEY. (*Elec. Rev. West. Elect.*, lix, 528.)—Gas mantles have a working life of 350 hours, carbon filament lamps have 800 to 1,000 hours, and metal filament lamps have 1,200 to 2,000 hours. Gas mantles fall to 80 per cent. candle-power in about 100 hours; carbon and flaming arc lamps do not suffer decadence in candle-power. Open arcs give only 10 to 15 burning hours. The Cooper-Hewitt mercury arc lamp falls to 75 per cent. candle-power in 1,000 hours, owing to a gray film deposit inside the tube, although the quartz type has a guaranteed life of 1,000 hours without appreciable deterioration. The Moore lamp does not blacken appreciably. Tungsten lamps are the least susceptible to voltage fluctuation of all incandescent lamps. Arc lamps do not require so close a regulation, but excessive pressure must be avoided, as the automatic feeding coils give long, unstable, and inefficient arcs. The power factor of filament lamps is practically 100 per cent.; that of arc lamps is 80 to 90 per cent. and the Moore tube is 90 per cent.

Paper Pulp from Eucalyptus. ANON. (*Paper Making*, xxx, 376.)—Samples of pulp of excellent quality have been prepared from the eucalyptus (blue gum), which has been planted over large areas in Southern California. The pulp is strong, clean, and slightly reddish, owing to the action of the alkali. Experiments with this wood as a raw material for paper pulp leave no doubt as to its suitability for the purpose. A sufficient growth of blue gum may be obtained in from four to six years; the stump yields a further good growth three years after the first cutting.

Helium Tubes as Light Standards. P. G. NUTTING. (*Washington Acad. Sci. Journ.*, 1, 221.)—Capillary tubes of about 2 mm. bore containing helium gas have shown useful characteristics as standards of light. The tubes are subjected to a high-tension discharge, the standard current being 25 milliamperes; a consumption of 3.8 watts per candle-power is then obtained. The light is furnished mainly by six prominent spectrum lines. These all increase in intensity uniformly with increasing current, and the connection is approximately linear. Neither voltage nor frequency affects the light appreciably, and the gas density has little effect between the limits of 3 to 8 mm. pressure. A test of the reproducibility of candle-power was made on forty tubes. The average deviation was 1.15 per cent., the maximum 3 per cent.

Results of Experiments with a Water-Tube Boiler with Special Reference to Superheating. HAROLD E. YARROW. (The Fifty-third Session of the Institution of Naval Architects, March 28, 1912.)—The object of this paper is to show the advantages of superheating, in marine engineering, when using a water-tube boiler.

The objections hitherto raised to superheating for marine work have been:

(1) Owing to the dryness of the steam, oil for the internal lubrication in reciprocating engines becomes a necessity, and the oil, finding its way into the boiler, leads to trouble.

(2) The probability of burning the superheater when the passage of the steam through it is suddenly reduced or stopped.

By the introduction of turbines the difficulty of lubrication does not occur, and with regard to burning the superheater tubes, the arrangement adopted avoided this risk.

The boiler experimented on was of the Yarrow type, and oil fuel only was used, hence it was possible to maintain steady and uniform working conditions.

During the experiments careful records were taken of the oil consumed, the water evaporated, steam pressure, temperature of the superheated steam, and the temperature of the gases at various points during their passage past the boiler tubes.

On the left-hand side of the boiler was the superheater, and on this side of the boiler there were fewer rows of generator tubes than on the other side, it being thought desirable that the total heating surface and the resistance to the gases on both sides of the boiler should be approximately the same. The total heating surface of the boiler was 6,700 square feet, of which 1,265 square feet consisted of superheating surface; the total heating surface of the superheater side of the boiler was 3,453 square feet, and on the other side 3,247 square feet. The superheater consisted of a number of "U" tubes expanded into two longitudinal collectors, small doors being fitted so that access could be obtained to the tubes when required. A damper was fitted in the up-take on the same side. When this damper was closed the whole of the gases were deflected towards the opposite side of the boiler, and no heated gases passed the superheater, so that if the main engines were suddenly eased or stopped, or when raising steam, the superheater might be shut off, so as to prevent the tubes being damaged, or the steam being superheated to an excessive extent, owing to there not being sufficient circulation of steam. In this way one objection to the introduction of superheating for marine installations was overcome.

In order to carefully measure the temperature of the superheated steam and of the gases, a complete installation of thermometers and pyrometers was fitted to the boiler.

With the damper open, at the maximum rate of evaporation,

namely, when burning 1,237 pounds of oil per square foot of heating surface per hour, the degree of superheat was 93°. Tests, burning oil fuel at a rate of consumption considerably greater than has hitherto been the custom, to ascertain if the boiler would, under such conditions, show any defects, were carried out for purposes of information. Nearly 2 pounds of oil per square foot of heating surface per hour were consumed—if the heating surface on the superheater side of the boiler be disregarded. Thus, the surface on the opposite side of the superheater was subject to the heating effects of all the gases plus half the radiation. Every part of the boiler withstood the severe test, and trials burning this quantity of fuel were made on several occasions.

The results of other experiments indicated that in a properly-designed boiler of the type dealt with it was possible to burn, without injury to the boiler, 2 pounds of oil per square foot of heating surface per hour.

Since these experiments were carried out official trials have taken place with one of the British Admiralty destroyers, H. M. S. Archer, in which boilers fitted with superheaters were provided. The result of these trials showed that the gain expected was fully realized, and on the full-speed trial the degree of superheat at the turbines was 94°, the S. H. P. developed was slightly over 18,500, which compared with about 17,000, the S. H. P. expected had the boilers been of the usual type. The mean speed for eight hours was 30.3 knots, the contract speed being 28 knots.

One outcome of the experiments was the proposition to have in some cases an additional damper on the opposite side to the superheater, the two dampers being arranged so that either can be open, or both open, but under no condition can both be closed. This enables the superheater side of the boiler to be used to a greater or less extent, as desired. When cruising at a slow speed this arrangement may possibly lead to a more economical result than if both sides of the boiler are equally free for the passage of the hot gases.

Judging by the best practice in land installations, 100° F. superheat is by no means the limit that can be adopted with advantage. It is reasonable to suppose that the requisite condition to be desired is that the steam should remain in gaseous form so far as possible during its passage through the turbine, because any condensation that takes place must diminish the energy given out by the steam to the blades of the turbine; also, if the steam remains in gaseous form, the steam friction is reduced.

The Utilization of Atmospheric Nitrogen.—The importance of nitrogenous compounds to the agricultural and industrial interests of Europe and America has promoted the Bureau of Manufactures to issue a monograph on the subject of utilizing atmospheric nitrogen in the production of such compounds.

The nitrogen problem, one of the most pressing of the twentieth century, is unique from the fact that the material is unlimited. The atmospheric nitrogen above one square mile of land, amounting to about 22,000,000,000 tons, is equivalent to what the world would require in the next fifty years at the present rate of consumption. The problem is to utilize this nitrogen economically, and thus free the world from its dependence on the nitrates of Chile, which are not particularly extensive and are likely to be exhausted at a comparatively early date.

Remarkable results have been obtained in Norway by means of electric furnaces in which atmospheric nitrogen is oxidized to the form of nitric oxide, which is caused in making calcium nitrate, or Norway saltpetre. This Norwegian product is already an important rival of Chile saltpetre, but as the success of the process depends upon a very cheap supply of electricity it will probably not be used to any great extent in the United States until the furnaces have been made more efficient.

Cyanamide, another nitrogenous fertilizer of growing importance, is being manufactured in America, and the industry should prove successful, as the production in this country of the calcium carbide required by the process is second only to that of Norway.

The monograph describes in detail the results obtained by the leading European chemists in their efforts to increase the supply of nitrogenous compounds, and the commercial as well as the technical aspects of the new industry are dealt with at length. The author, Thomas H. Norton, Consul at Chemnitz, Germany, on detail as commercial agent of the Department of Commerce and Labor, states, in conclusion, that the achievements of applied chemistry make it possible for American industry and agriculture to face with confidence the threatened exhaustion of the nitrate deposits of Chile.

The Growth of Plants Aided by Electricity. F. L. COOKE. (*Elect. Rev. West. Elec.*, lix, 975.)—This is an account of experiments made by *Glaede* on the stimulation of plants by high-tension electric currents. In hot-house beds a single galvanized iron wire was embedded in the soil. A network of wires forming about a 12-inch mesh was placed about four feet above, insulated from the supports. Short brass chains were suspended at frequent intervals along this network. A current of 600 cycles, at 250,000 volts, was applied to the two sets of conductors, and thus an electric field was formed in the space occupied by the flower beds. Chrysanthemums grew much more rapidly, were much stronger and hardier, and showed twice as many blooms per plant. Fungus growths in the soil were killed. Roses and carnations gave four times the ordinary yield, and a marked absence of stem-rot was noticed. With a similar arrangement in the open air garden, radishes were grown three inches in diameter, which retained their flavor and were

neither pulpy nor stringy. Tomatoes and corn grew to unusual size, at the same time keeping their uniformity of shape. Muskmelons developed rapidly and yielded an enormous crop. Melons and beets were noticeably sweeter.

Pulverization of Metals by the Oscillating Discharge. J. DE KOWALSKI and E. BANASINSKY. (*Arch. des Sci.*, xxxii, 468.)—It has been shown that metallic electrodes employed in the production of an oscillating discharge of a condenser are pulverized. The metals may be arranged, in descending order of degree of pulverization, as follows: gold, platinum, zinc, iron, copper, silver, aluminum. It is now shown that the effect increases with the explosive distance whatever metal is used, and that it diminishes with the capacity, this being more pronounced for large than for small explosive distances.

Electrical Resistivity of Special Steels. O. BOUDOUARD. (*Comptes Rendus*, cliii, 1475.)—The resistance of nickel, manganese, chromium, and tungsten steels was determined by Kelvin's method. Two series of alloys with each metal were made, one containing 0.1 to 0.2 per cent. of carbon, and the other 0.8 to 0.9 per cent. of carbon. The general results were: in carbon steels the resistance increases with the carbon content. With constant nickel, carbon considerably increases the resistance, and the curve passes through a maximum approximately corresponding to the formula $Ni\,Fe_2$. Carbon appears to have very little effect on the manganese steels, otherwise there appears to be a maximum corresponding to 12 to 13 per cent. manganese. In the chromium series irregularities arise regardless of the carbon content. The resistances of tungsten steels are not affected to any considerable extent by the state of the metal, whether hard, annealed, or ordinary, but the curve appears to pass through a maximum, then through a minimum, and finally increases rapidly. Application of Benedick's formula to the carbon steels gives results in good agreement with the observed figures, but the formula does not apply to special steels except in indicating the specific influence of a metal on the resistance of the steel under consideration.

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